SUTHERLAND SHIRE COUNCIL

WOOLOOWARE BAY FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

FEBRUARY 2022

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FINAL

FEBRUARY 2022

Project **Woolooware Bay Floodplain Risk Management Study and Plan**	**Project Number** **119011**
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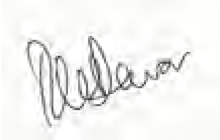
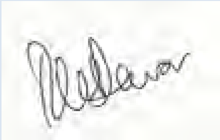
Authors Tom Piovesan Paul Grech Richard Dewar	**Prepared by:** 
Date 11 February 2022	**Verified by** 

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LIST OF ACRONYMS

AAD	Annual Average Damages
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ALS	Airborne Laser Scanning or known as LiDAR
ARF	Aerial Reduction Factor (for rainfall)
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff 1987 / 2019 editions
BCA	Building Code of Australia
BoM	Bureau of Meteorology
CDC	Complying Development Certificate
DA	Development Application
DCP	Development Control Plan
DEM	Digital Elevation Model
DoP	Department of Planning
DRAINS	Hydrologic model
ELVIS	Elevation Information System
ERP	Emergency Response Planning
EP&A Act	Environmental Planning and Assessment Act
EY	Exceedances per Year
FERC	Flood Emergency Response Classification
FIA	Flood Impact Assessment
FPA	Flood Planning Area
FPCC	Flood Planning Constraint Categories
FPL	Flood Planning Level
FRM	Floodplain Risk Management
FRMS&P	Floodplain Risk Management Study and Plan
GIS	Geographic Information System
GPT	Gross Pollutant Trap
LEP	Local Environmental Plan
LGA	Local Government Area
LiDAR	Light Detection and Ranging or known as ALS (Airborne Laser Scanning)
mAHD	meters above Australian Height Datum
OSD	On Site Detention
OSR	On Site Retention
PMF	Probable Maximum Flood
RAMSAR	Ramsar Convention on Wetlands of International Importance especially as Waterflow Habitat
SES	State Emergency Services
SMS	Short Messaging Service
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood hydraulic computer model
WSUD	Water Sensitive Urban Design

FOREWORD

The NSW State Government's Flood Policy provides a framework to ensure the sustainable use of floodplain environments. The Policy is specifically structured to provide solutions to existing flooding problems in rural and urban areas. In addition, the Policy provides a means of ensuring that any new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Policy, the management of flood liable land remains the responsibility of local government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist councils in the discharge of their floodplain management responsibilities. The Federal Government may also provide subsidies in some circumstances.

The Policy provides for technical and financial support by the Government through four sequential stages:

1. Flood Study
- Determine the nature and extent of the flood problem.

2. Floodplain Risk Management Study
- Evaluates management options for the floodplain in respect of both existing and proposed development.

3. Floodplain Risk Management Plan
- Involves formal adoption by Council of a plan of management for the floodplain.

4. Implementation of the Plan
- Construction of flood mitigation works to protect existing development, use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

The Woolooware Bay Floodplain Risk Management Study & Plan (FRMS&P) presented herein constitutes the second and third stages in the NSW Floodplain Risk Management process for the Woolooware Bay catchment and follows on from the Flood Study prepared by WMAwater in March 2014. WMAwater and GLN Planning were engaged by Sutherland Shire Council to prepare this FRMS&P.

GLN Planning undertook a review of the planning components for this FRMS&P and this is included in Appendix D.

This report has been prepared with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Department of Planning, Industry and Environment (DPIE).

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TERMINOLOGY USED IN REPORT

Australian Rainfall and Runoff (ARR) have produced a set of guidelines for appropriate terminology when referring to the probability of floods. In the past, AEP has generally been used for those events with greater than 10% probability of occurring in any one year, and ARI used for events more frequent than this. However, the ARI terminology is to be replaced with a new term, EY.

Annual Exceedance Probability (AEP) is expressed using percentage probability. It expresses the probability that an event of a certain size or larger will occur in any one year, thus a 1% AEP event has a 1% chance of being equalled or exceeded in any one year. For events smaller than the 10% AEP event however, an annualised exceedance probability can be misleading, especially where strong seasonality is experienced. Consequently, events more frequent than the 10% AEP event are expressed as X Exceedances per Year (EY). Statistically a 0.5 EY event is not the same as a 50% AEP event, and likewise an event with a 20% AEP is not the same as a 0.2 EY event. For example, an event of 0.5 EY is an event which would, on average, occur every two years. A 2 EY event is equivalent to a design event with a 6-month average recurrence interval where there is no seasonality, or an event that is likely to occur twice in one year.

While AEP has long been used for larger events, the use of EY is to replace the use of ARI, which has previously been used in smaller magnitude events. The use of ARI, the Average Recurrence

Interval, which indicates the long-term average number of years between events, is now discouraged. It can incorrectly lead people to believe that because a 100-year ARI (1% AEP) event occurred last year it will not happen for another 99 years. For example, there are several instances of 1% AEP events occurring within a short period, for example the 1949 and 1950 events at Kempsey.

Where the % AEP of an event becomes very small, for example in events greater than the 0.02 % AEP, the ARR terminology suggest the use of 1 in X AEP so a 0.02 % AEP event would be the same as a 1 in 5,000 AEP.

The PMF is a term also used in describing floods. This is the Probable Maximum Flood that is likely to occur. It is related to the PMP, the Probable Maximum Precipitation.

This report has adopted the approach of the ARR terminology guidelines and uses % AEP for all events from the 50% AEP and greater and EY for all events smaller and more frequent than this. The image below provides the relationship between the various terminologies.

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	20
	0.02	2	50	50
	0.01	1	100	100
Very Rare	0.005	0.5	200	200
	0.002	0.2	500	500
	0.001	0.1	1000	1000
Extreme	0.0005	0.05	2000	2000
	0.0002	0.02	5000	5000
			PMP/ PMPDF	

The blue shaded areas represent the terminology adopted in this report.

BRIEF OUTLINE OF HOW DESIGN FLOOD LEVELS ARE CALCULATED

There are two broad approaches for calculating design events (floods of a known probability of occurrence such as the old 100-year event now termed the 1% AEP). The first is to undertake statistical analysis (termed flood frequency analysis) of a long record of peak flood levels (such as recorded for over 100 years at Windsor). This approach is rarely used (and not possible for the Woolooware Bay catchment) as there are few places where these accurate long-term records exist. The alternative method (termed rainfall runoff modelling) is to use computer models of the catchment which calculate peak flood levels (based on equations of flow) from design rainfall data provided by the Bureau of Meteorology (BoM). The BoM can calculate design rainfall depths across Australia based on an extensive and long-term record of historical rainfalls. The accuracy of the computer models is increased by "calibrating" them to historical flood height data using the actual rainfall records from that historical event. The models include detailed definition of the topography derived from laser aerial scanning of the ground (this data has a vertical accuracy of around +/- 150mm and is available at approximately 1m spacings).

EXECUTIVE SUMMARY

STUDY OBJECTIVES

The NSW Government's Flood Policy provides for:

- *a framework to ensure the sustainable use of floodplain environments,*
- *solutions to flooding problems,*
- *a means of ensuring new development is compatible with the flood hazard.*

Implementation of the Policy requires a four-stage approach, the first of which is preparation of a Flood Study to determine the nature and extent of the flood problem and has been completed. The main objective of the second and third stage, namely this Floodplain Risk Management Study and Plan is to identify floodplain risk, analyse floodplain strategies for the management of risk and to put forward priorities and approximate costed recommendations regarding flood risk mitigation in the catchment.

Floodplain risk management must also be considered, and where practicable, integrated with other management approaches such as stormwater, asset and catchment management. It is also envisaged that the work undertaken for this FRMS&P can serve as a basis for improving floodplain risk management across the Shire.

CATCHMENT DESCRIPTION

The Woolooware Bay catchment (Figure 1 and Photo 1) has an area of approximately 6 km^2 and is located within the Sutherland Shire Local Government Area (LGA) with the lower area part of the Georges River floodplain.

Photo 1: Woolooware Bay Study Area

Land use in the catchment is predominately residential with industrial and recreation lining the foreshore of Woolooware Bay. Parts of the pre-European settlement mangrove swamps found around the Bay area were later reclaimed to create parks and playing fields including Endeavour Field (Shark Park), Woolooware Golf Course and Cronulla Golf Course. The catchment slopes from south to north towards the Bay with the lower reaches typically flat and low lying. The catchment is drained primarily by a Council owned sub-surface pipe system, with natural earth drainage channels located downstream in the golf courses.

A combination of flat topography and proximity to Woolooware Bay makes a large portion of the downstream areas susceptible to flooding. The governing flood mechanisms for this part of the catchment where the two golf courses are located include local runoff and tidal inundation. Captain Cook Drive, which is situated along the downstream end of the catchment boundary, acts as a significant barrier to runoff from entering Woolooware Bay.

PAST STUDIES

The March 2014 Woolooware Bay Flood Study (Reference 1) established a computer model (TUFLOW) which was calibrated to limited historical flood data and used to determine design flood levels, depths, and velocities for a range of design flood events.

STAKEHOLDER AND COMMUNITY CONSULTATION

Throughout this study there has been consultation with the key stakeholders as well as with the community through the floodplain management committee, newsletters, questionnaires, and workshops. Consultation during the preparation of the FRMS&P was undertaken primarily with the Sutherland Shire Floodplain Management Committee as well as staff from SES and DPIE. An online workshop was held on 23 September 2021 with several local consulting engineers who provided valuable feedback on their experience with the implementation of flood-related development controls as well as the proposed updates to DCP Chapter 40.

The Floodplain Management Committee at its meeting of 12 October 2021 endorsed the draft FRMS&P report for presentation to Council subject to making some recommended changes. Several community engagement methods were undertaken during the four week public exhibition of the draft FRMS&P report in December 2021. This included uploading of the draft FRMS&P report to Council's Join the Conversation website together with supporting documents, photographs of flooding, frequently asked questions, a summary brochure and list of survey questions. Where applicable, Council officers responded to individual questions and prepared a summary of all enquiries.

EXISTING FLOOD PROBLEM

One of the most recent significant flooding that occurred within the catchment is the May 2003 event. This event has been well-documented with newspaper reports and correspondence received by Council recording damage to factories, houses and motor vehicles. Many of the community complaints were recorded on Council's customer response management system. Another known event occurred in March 1975 which caused widespread flooding throughout Sydney, mainly in Sans Souci, but including parts of the Sutherland Shire though at Woolooware the magnitude of the event cannot be accurately determined.

Flooding of Captain Cook Drive and the golf courses has also been reported for frequent events.

Community consultation undertaken as part of the March 2014 Woolooware Bay Flood Study (Reference 1) indicated that 5 building floors have been inundated in the past and 21 complaints of flooding on properties noted. It should be noted that these numbers are likely to be underestimates.

Photo 2 is an aerial photograph which indicates the extent and depth of inundation in the 1% AEP event and the significant areas of inundations termed hotspots.

Photo 2: 1% AEP Flood Extent, Depth and Identified Hotspots

The FRMS&P outlines the economic, social and environmental impacts of flooding. There are some 600 properties affected in the 1% annual exceedance probability (AEP) flood event, formerly known as the 100 year average recurrence (ARI) event, approximately 100 of which are affected by above-floor flooding. When averaged over all floods up to the probable maximum flood (PMF), flooding is estimated to cause tangible average annual damages of approximately three million dollars. Flooding can also lead to intangible damages such as inconvenience and stress, and cause traffic disruption through closure of flood affected roads such as Captain Cook Drive, Gannons Road and the Kingsway.

PREVIOUS FLOOD MITIGATION MEASURES UNDERTAKEN

There are no existing flood mitigation measures within the catchment apart from Council's pit and pipe network and a small open channel system in North Cronulla parallel and to the east of Wyanbah Road. Cronulla Golf Course has raised several of its fairways to improve the playability of the course and Woolooware Golf Course has constructed bridges to improve access.

FLOODPLAIN MANAGEMENT PLANNING CONSIDERTIONS

GLN Planning undertook a review of the planning components for this FRMS&P and this is included in Appendix D.

POSSIBLE FLOODPLAIN MANAGEMENT MEASURES

Management measures can be subdivided into flood modification (change the nature of flooding), property modification (change to the property) or response modification (changes the response of people) measures as summarised below.

Flood Modification	Property Modification	Response Modification
Levees	Land zoning	Community awareness
Temporary defences	Voluntary purchase	Flood warning
Channel construction	Building & development controls	Evacuation planning
Channel modification	Flood proofing	Evacuation access
Major structure modification	House raising	Flood plan / recovery plan
Drainage network modification	Flood access	
Drainage maintenance		
Retarding basins		

Each possible measure must be investigated considering the positive and negative social, economic, hydraulic and environmental effects. As a result, many measures are eliminated. For small, fully urbanised and highly constrained overland flow catchments like the Woolooware Bay catchment, it is very difficult to address existing flood risk through structural flood modification measures such as detention basins, levees and channel enlargements. Traditional behaviour modification measures such as flood warning and evacuation are also constrained by short flood warning times and the short duration of flooding.

The greatest potential for reducing existing flood risk in the Woolooware Bay catchment is through property modification measures, most importantly the redevelopment of flood-affected buildings and the application of flood-related development controls. This typically involves replacing an older, low-set building affected by above-floor flooding with a flood compliant high set building. Where redevelopment involves intensification, that is, increasing the number of people in the floodplain (through for example multi-dwelling development), this may result in increased intangible damages.

Several principles for floodplain risk management were subsequently identified in the FRMS&P including:

• encourage redevelopment but not intensification of flood affected properties;
• the level of flood-related development control should be commensurate with development vulnerability and flood risk;
• property modification measures and behaviour modification measures should be mutually supportive; and
• community self-reliance.

Various opportunities for floodplain risk management were initially identified such as:

- clarify appropriate development approval pathways, for example, complying development or development application (DA).
- update Chapter 40 of the DCP to better reflect development vulnerability and common types of development, incorporate flood-related development principles, and provide greater guidance on the application of flood-related development controls.
- explore market based and regulatory mechanisms to incentivise flood affected property owners to reduce flood risk on their property.
- improve flood emergency response by examining options for raising community flood awareness, providing more timely flood warnings and allowing shelter-in-place during flooding.
- consider more strategic floodplain risk management measures that would support property modification and behaviour modification measures.

The FRMS&P considered structural flood modification measures in detail. These included flood detention basins in public open space across the middle and upper reaches of the catchment, and enlarging open channels and culverts located at the base of the catchment. No cost-effective flood modification measures were identified. Stormwater and waterway management measures such as stormwater pipe upgrades and increased maintenance to reduce the risk of network blockages, were considered effective in reducing flood levels and duration only in very minor flood events and for localised areas.

Two types of property modification measures were considered, being regulatory mechanisms and market-based incentive mechanisms. For the former, it was found that although the application of flood-related development controls generally achieved flood compliant development, there was an opportunity to update the DCP to reduce the time and effort taken to prepare, submit and assess DAs. Specifically, this would involve updating the existing risk and land use development control matrix in the DCP to better reflect development type and vulnerability, incorporate flood-related development principles, update specific controls and prepare technical guidelines for flood impact assessment to support the application of controls.

It was also considered that the administrative burden on development proponents and Council relating to DAs could be reduced by allowing complying development within the low flood risk precincts (such as the area between the 1% AEP flood extent and the PMF) without increasing the risk associated with any potential non-compliant development. Guidance could be given in the updated DCP and elsewhere on choosing the most appropriate development approval pathway.

Market-based incentive mechanisms are designed to encourage flood-affected property owners to take action to reduce flood risk on their property sooner than they would have otherwise. Voluntary purchase and voluntary house raising are two common approaches, however, no suitable flood-affected properties were identified for these approaches in the Woolooware Bay catchment.

The FRMS&P considered options for voluntary redevelopment, voluntary flood proofing and voluntary fence modification. Voluntary redevelopment involves providing a financial or planning-related incentive to encourage the early knock-down of a flood affected building and the development of a flood-compliant building. Voluntary flood proofing and voluntary fence modification involve providing a financial incentive to flood proof an existing building or modify the boundary fence of a property to make it flood compatible, to reduce flood damages. These measures all require more detailed investigation and consultation to confirm their feasibility.

Several behaviour modification measures were canvassed. There may be an opportunity, in consultation with the Bureau of Meteorology (BoM) and the State Emergency Service (SES), to develop a flash flood warning system utilising a telemetered network of pluviometers such as those operated by Sydney Water across the Sutherland Shire. A broader community flood awareness program could also be developed that would encourage property owners, particularly those affected by above-floor flooding, to access available flood data, plan for floods, undertake minor property modification measures and to work with neighbours before and during floods.

The findings from the FRMS&P can be provided to the SES to update their Flood Emergency Sub Plan and better prepare for overland flooding and road closures.

Finally, the FRMS&P considered strategic floodplain risk management measures that would support the property and behaviour modification measures discussed above. These include improving the management of flood data (including the use of data for flood insurance), addressing the cumulative impact of ongoing development, reviewing the use of on-site detention or retention to reduce flood risk over time, opportunistic upgrade of stormwater pipes and addressing issues at specific hotspots such as Woolooware Golf Course and Captain Cook Drive. Many of these measures would be integrated with and implemented using existing stormwater, waterway, asset and catchment management approaches.

FLOODPLAIN MANAGEMENT PLAN OUTCOMES

In summary no significant flood modification measure is proposed and the Plan (Section 10 and Table 19) relies upon property and response modification measures. The table below is a summary of the key actions recommended in the FRMS&P, their indicative costs and the projected timeframe to commence and finish. Timeframes have been classified as immediate (2022/23), short term (1 - 2 years) and medium term (3 – 8 years) and have been allocated based on consideration of available resources, competing priorities and predicted funding. Costs will be updated based on more detailed scoping, available funding and market responses.

Recommended Key Actions	Indicative Cost	Projected Start	Projected Finish
Strategic Floodplain Risk Management Measures			
Flood data management improvements	$100,000	Immediate	Medium
On site detention policy review and update	$100,000	Immediate	Short
Stormwater, waterway, asset and catchment management integration	Internal cost	Short	Medium
Behaviour Modification Measures			
Flood access, road closures and notification improvements	$20,000	Short	Short
Flash flood warning system detailed feasibility assessment	$60,000	Short	Short
Community flood education and awareness program development	$70,000	Short	Medium
Property Modification Measures			
DCP update and flood impact assessment guideline development	Internal cost	Immediate	Short
Voluntary redevelopment detailed feasibility assessment	$60,000	Medium	Medium
Voluntary flood proofing detailed feasibility assessment	$60,000	Medium	Medium
Voluntary fence modification detailed feasibility assessment	$70,000	Medium	Medium

1. INTRODUCTION

1.1. Background

This report has been prepared by WMAwater and GLN Planning on behalf of Sutherland Shire Council and details; the Woolooware Bay Floodplain Risk Management Study and Plan (FRMS&P). The FRMS&P follows on from the Woolooware Bay Flood Study (Reference 1) undertaken by WMAwater and completed in March 2014 which defined the design flood behaviour in the Woolooware Bay catchment under existing conditions.

The main objective of this FRMS&P is to identify floodplain risk, analyse cost effective measures for the management of risk and to put forward priorities and approximately costed recommendations regarding flood risk mitigation in the catchment. To support this Council prepared the project narrative as shown in Diagram 1.

Diagram 1: Project Narrative Provided by Council

Overall Goal

Reduce the risk to life and property from overland flooding in the Woolooware Bay catchment

↓

Project Outcome

Deliver a set of prioritized, cost-effective and coordinated FRM options for progressive implementation over the life of the FRMS&P for the benefit of flood-affected property owners and the wider community

↓

Project Output

FRMS&P report, flood models and GIS data

↓

Project Activities

Data compilation, flood model update, FRM option assessment, FRMS&P report preparation

The context and drivers for this project are summarised below.

- Technological advances
  - More data
  - Improved modelling technology and practices
  - Inclusion of ARR 2019
- Integration with stormwater, asset & catchment management
  - Acknowledge cross-over between stormwater management and floodplain risk management (FRM)
  - Model outputs to help set performance-based criticality ratings for stormwater assets
  - FRMS&P to assist with broader catchment management particularly on site detention and on site retention (OSD, OSR), watercourse management and impacts of sedimentation on flow conveyance
- Need to update the Sutherland Shire Development Control Plan (DCP)
  - Property modification measures will be the most cost-effective of the three categories

of FRM measures
    - Existing DCP is not well suited for addressing overland flow situations
    - Flood mapping has been prepared at different times by different people using different methodologies for different purposes. Mapping needs to be updated, made consistent, and consolidated within one place
    - Quality of flood impact assessment for developments varies widely
- Template for other overland FRMS&Ps
    - Project provides a basis for undertaking FRM in other catchments
    - Opportunity to consider and potentially integrate latest flood policy work and FDM updates

A range of management options to effectively manage existing, future, and continuing flood risks in the catchment was considered. The outcomes from this FRMS&P will also assist the SES in updating the Local Flood Plan for the catchment. The FRMS&P has been undertaken in accordance with the guidelines provided in the NSW Floodplain Development Manual (Reference 2).

The study covers the Woolooware Bay catchment in the Sutherland Shire LGA. This area is largely a residential area with adjoining areas of open space. Apart from the land adjoining Woolooware Bay / Georges River there are no river/creek systems except for vegetated channels within Woolooware and Cronulla Golf Courses and a lined open channel (< 1m wide) that runs parallel to Wyanbah Road, from south of Burke Road to Bando Road. Flooding within the study area is therefore termed overland flow flooding as opposed to mainstream or riverine flooding that occurs from river systems such as the Georges River. Overland flow flooding is described as inundation by runoff occurring where there is no (or very little) defined open channels (such as a creek, lake or river).

Typically, in overland flow areas the depth of flow is less than 0.5m deep and occurs infrequently as the pit and pipe stormwater drainage system largely eliminates inundation in frequent events (say up to an event that occurs on average once in every 5 years - termed a 20% AEP event).

This FRMS&P is consistent with the objectives for floodplain risk management studies and plans given in the NSW Flood Prone Land Policy. This includes:

- Reduce the flood risk to people and property in the existing community.
- Ensure future development is controlled in a manner consistent with the flood risk (considering the potential impacts of climate change).
- Reduce private and public losses due to flooding.
- Protect and where possible enhance the creek and floodplain environment.
- Be consistent with the objectives of, the Government's Flood Prone Land Policy and gazetted Floodplain Development Manual (2005 – Reference 2).
- Ensure that the floodplain risk management plan is fully integrated with Council's existing corporate, business and strategic plans, existing and proposed planning proposals, meets Council's obligations under the Local Government Act 1993, and has the support of the local community.
- Ensure actions arising out of the plan are sustainable in social, environmental, ecological

and economic terms.

- Ensure that the floodplain risk management plan is fully integrated with the local emergency management plan (flood plan) and other relevant catchment management plans, and to
- Establish a program for implementation and suggest a mechanism for the funding of the plan which should include priorities, staging, funding, responsibilities, constraints, and monitoring.

1.2. Methodology

The methodology undertaken was based on that provided in the NSW Floodplain Development Manual (Reference 2). Initially this involved data collection and review which fed into updating of the hydrologic and hydraulic modelling undertaken in the 2014 Flood Study. The next stage was to undertake a flood damages assessment which is necessary to assess the viability of the floodplain management measures.

A preliminary assessment of management measures was undertaken which led to more detailed assessment of the most viable measures.

The project was overseen by Council's Floodplain Management Committee. Numerous stakeholders were consulted including Council staff, DPIE, SES, local consulting engineers and Woolooware Golf Club.

Initial stages of the project included undertaking a user needs analysis and an update to the modelling undertaken in the 2014 Woolooware Bay Flood Study (Reference 1). Additional work that is not always undertaken in a FRMS&P included a drainage capacity network analysis and a review of the cumulative flood impact assessment. Of significance was to include integration with catchment and waterway management.

A key component was the need to thoroughly review the planning aspects of floodplain management and this work was undertaken by GLN Planning and is provided as Appendix D. This work included a review of flood risk precincts, the flood planning level, flood controls, the use of covenants, flood compatible fencing, flood control lots and approval pathways.

Updated flood study mapping was formally adopted by Council during the project which led to flood notations being added and removed for various properties. Flood notations were also updated in accordance with the NSW Government's flood prone land package update of July 2021.

The outcome of this project is a series of recommended management measures as shown in Section 10.

2. CATCHMENT DESCRIPTION

2.1. Overview

The Woolooware Bay catchment is located approximately 20 km south of the Sydney CBD within the Sutherland Shire Council LGA and forms part of the lower Georges River floodplain (Figure 1). It is bound by Botany Bay to the north, Bate Bay sub-catchment to the east, Gwawley Bay sub-catchment to the west and Port Hacking sub-catchment to the south. The catchment includes the suburbs of Taren Point, Caringbah, Woolooware, and Cronulla.

The Woolooware Bay catchment has an area of approximately 6 km^2. The catchment slopes from south to north towards the Bay with the lower reaches typically flat and low lying.

Figure 2 shows the existing land use of the study area. Most of the catchment is low density residential development with medium and high density residential along the main transport routes and in north Cronulla. The two main large areas of open space are Woolooware and Cronulla golf courses which are partially on reclaimed land. General industrial, light industrial and business park activities are in the northwest fronting Woolooware Bay.

Mangrove swamps are found around the Bay area. Some swamps were later reclaimed to create parks and playing fields including Endeavour Field (Sharks football park), Woolooware and Cronulla Golf Courses. The two golf courses located in this part of the catchment are both subjected to tidal inundation along their open channels.

2.2. Drainage System and Flood Mechanism

The catchment is drained primarily by a Council owned sub-surface pipe system, with natural earth drainage channels located downstream in the golf courses. There are approximately 2,100 drainage pits and stormwater pipes / culverts within the catchment. Floodwater discharges into Woolooware Bay primarily through the tidal channels and pipes found along the downstream boundary of the catchment.

As the catchment is subdivided by the Sutherland / Cronulla railway line (Figure 1) limited overland flow paths exist for the upstream catchments, such as at Gannons Road. Typically, during major flood events, the culverts underneath the railway line only have sufficient capacity to convey a small proportion of the peak flood discharges from the upper parts of the catchment. As a result, excess floodwaters tend to “build up” behind the railway embankments, forming temporary flood storage areas with the main exit at Gannons Road.

A combination of flat topography and proximity to Woolooware Bay makes a large portion of the downstream areas susceptible to flooding. The governing flood mechanisms for this part of the catchment where the two golf courses are located, include local runoff and tidal inundation. Captain Cook Drive, which is situated along the downstream end of the catchment boundary, acts as a significant barrier to runoff from entering Woolooware Bay. Large quantities of floodwaters flow from the Woolooware Golf Course onto Captain Cook Drive and subsequently onto the playing fields downstream. Several gross pollutant traps (GPTs) are also installed in the catchment, mostly in the golf courses as well as at the outlets entering the Bay.

2.3. History of Flooding

One of the most recent significant floods that occurred within the Woolooware Bay catchment is the 13th to 16th May 2003 event. This event has been well-documented with newspaper reports and correspondence received by Council recording heavy damages to factories, houses and motor vehicles. Many of the community complaints were recorded on Council's Customer Response Management System, of which a total of 68 complaints were in the vicinity of the study area. These complaints can be further sub-divided into the following categories:

- Reference to flooding above floor level - 5 complaints.
- Reference to flooding on property - 21 complaints.
- Reference to flooding on roadways - 2 complaints.
- Reference to drainage maintenance issues - 25 complaints.
- Issues unrelated to flooding - 15 complaints.

These complaints were evenly distributed across the catchment. Most complaints referred to flooding on residential properties and only three provided estimates of inundation depths. The other issues raised by these complaints were insufficient drainage and blocked drains.

Several historic photos have been obtained that highlight the potential magnitude of flooding in the region. Photo 3 shows flooding of Captain Cook Drive at the intersection with Gannons Road for the March 1975 event. This event was known to have caused widespread flooding throughout Sydney and the rainfall was documented by the BoM who estimated that based on rainfall records at Miranda, this event may have approached a 1 in 1000 ARI over a 12-hour duration and a 1 in 400 ARI for a 2-hour duration. This event caused widespread flooding in Sans Souci, Kogarah and in other parts of the Sutherland Shire. It is likely that the rainfall intensities would have varied greatly across the area and at this locality the magnitude of the event cannot be accurately determined.

It should be noted that Captain Cook Drive has been raised since 1975 and other works for the adjacent sporting fields and residential tower blocks will have changed the topography. It is likely that filling to create the sporting fields on the north (downstream) side of Captain Cook Drive will have increased flood levels upstream.

Since 2003 there have been several events that have caused flooding of Captain Cook Drive causing traffic disruption (there is video on YouTube of 12 March 2012 event). These events are likely to have a magnitude of less than 20% AEP and possibly even more frequent.

Flooding of the golf courses has also been frequently reported by the local media, residents (evident from the community consultation findings in the Flood Study) and Council. During a flood event, the golf courses serve as a temporary storage area for floodwaters. Woolooware Golf Course drains within approximately one day but Cronulla Golf Course takes two to three days and pumps are employed. Photo 4 to Photo 6 show what typically occurs at the golf courses after a major rainfall event.

Photo 3: Flooding at the corner of Gannons Rd and Captain Cook Dr, dated March 1975 (courtesy of Ross Myers)

Photo 4: Flooding in the Cronulla Golf Course, dated July 2011 (courtesy of the Leader)

Photo 5: Flooding on Captain Cook Drive May 2015 (courtesy of Sutherland Shire Council)

Photo 6: Flooding in the Woolooware Golf Course, date unknown (courtesy of the Woolooware Golf Club)

2.4. Demographic Overview

Understanding the social characteristics of the study area can help in ensuring appropriate risk management practices are adopted, and shape the methods used for community engagement. Census data regarding house tenure and age distribution can also provide an indication of the community's lived experience with recent flood events, and hence an indication of their flood awareness.

The 2016 Census for the suburbs was reviewed and in summary there is generally a higher proportion of English-speaking households and no large difference in age profile compared to the NSW average. These characteristics are considered in the community engagement strategy and when considering response modification options, such as flood education, warning or evacuation systems. Given the high proportion of English-only households, the delivery of community consultation material and flood warnings / information in English is deemed appropriate.

If there is a significantly higher proportion of residents over the age of 65 than the NSW state average in a local area, it is appropriate to consider that aged residents are more likely to be frail and unable to respond as quickly to flood emergencies. These residents may also prefer to receive hardcopy newsletters rather than via online methods. Provision of assistance to such residents should be a key consideration when developing flood evacuation systems and the lead time with which warnings are provided. The family composition (single parent or lone householder) within a residence can also affect flood awareness and the capacity to respond.

2.5. Environmental Overview

The remaining significant environmental features are in the lower parts of the catchment and include the two golf courses with their open channels and lakes, the mangrove lined channel to the west of the football stadium and the foreshore mangrove lined tidal areas. Post European settlement has removed the natural vegetation from the upper catchment, except along the remaining open drainage lines, and constructed the existing urban environment. The Woolooware golf course was originally a dairy farm and together with Cronulla golf course became uncontrolled land fill sites with the natural drainage lines and features significantly modified.

Parts of the lower floodplain will have acid sulphate soils and suffer from sediment contamination because of the prior uncontrolled land filling.

2.6. Catchment Development

The Woolooware Bay catchment is continually being re-developed as opportunities arise. The majority is redevelopment of existing residential lots.

Residential redevelopment typically comprises alterations & additions to existing dwellings, and “knock down and rebuild” of older single dwellings for dual occupancies or other forms of multi dwellings. This is generally occurring as the houses reach the end of their useable life, but more modern houses are also being re-developed. This trend has increased in recent times for a variety of reasons (rise in land prices, Covid, demand for houses close to the beach).

New subdivisions have occurred at Greenhills and Shearwater but runoff from these areas exit to the east of Cronulla Golf Course. Several new high-rise apartments have also been constructed along the Cronulla foreshore.

The most significant new residential development is adjacent to the football ground. Runoff from this development directly enters Woolooware Bay and a comprehensive flood impact assessment was undertaken. Thus, this development has had no impact on runoff but does increase the number of occupants within the floodplain. Re-development of Captain Cook Drive has also been undertaken but again a comprehensive flood impact assessment was undertaken.

There are few opportunities within the catchment for further large residential subdivision developments but there are opportunities for several small, isolated subdivisions. Extensive commercial and light industrial developments have occurred in the last 20 years at Taren Point but there are few remaining vacant non-residential lots.

3. DATA COMPILATION AND FLOOD MODELLING UPDATE

3.1. Available Data

The following key data were obtained at the commencement of the project:

- 2014 Woolooware Bay Flood Study Report (Reference 1) and data.
    - TUFLOW hydraulic models and results.
    - DRAINS hydrology models and results.
    - All survey data (cross sections, structure survey).
- GIS Data.
    - Aerial photography.
    - Topographic survey data in the form of airborne laser survey ALS/LiDAR.
    - Cadastre, layers and names for roads and creeks.
    - Land use zoning.
    - Stormwater drainage details including pit and pipe.
    - General GIS information (roads, watercourses, etc.).
- LEP and DCP and other planning policies.
- Any previous flood related studies/reports.

In addition, building floor level data were collected for use in the flood damages assessment (Section 5). Given the large catchment area and the number of flood affected properties, theodolite-based survey of the floor levels of all properties was not financially feasible. Details of how building floor levels were estimated are presented below:

- No surveyed floor levels data were available from previous studies.
- Floor level estimation was undertaken for approximately 1100 properties by WMAwater for the properties inundated in the 1% AEP event taken from the 2014 Woolooware Flood Study.
- The floor levels were estimated based on the ground level at the front door obtained by ALS plus the height of the floor above the ground (by counting bricks etc.).
- The height of the floor levels above the ground were estimated by visual inspection based on analysis of available digital imagery (Google Street View) or site inspection (refer Figure 3).

3.2. Update of March 2014 Woolooware Bay Flood Study (Reference 1)

The 2014 Flood Study defined the existing flood behaviour using a DRAINS hydrologic model and a TUFLOW hydraulic model based on Australian Rainfall & Runoff (ARR1987). A detailed review of the approach and outcomes are provided in Appendix F. As part of the present study the 2014 Woolooware Bay Flood Study was updated to incorporate the following changes:

- **Model Software:** The hydraulic model was converted to the 2018 HPC version of TUFLOW that allows the use of GPU hardware and an adaptive timestep. This significantly reduces the model runtime by over 10 times. Further details on TUFLOW HPC can be found at https://wiki.tuflow.com/index.php?title=HPC_Introduction. A comparison with the results from TUFLOW Classic generally indicated less than 0.1m change in peak level.
- **Topographic Survey:** Incorporation of 2013 ALS provided by Council and ELVIS.

- **Modelling Methodology:** A grid size of 1m was adopted rather than the previous 3m grid size. A comparison of results indicated that this made no significant difference to the results. Kerb and guttering are important in channelising and directing the flow along roads, particularly in small events. However, kerb and guttering cannot be accurately modelled at all locations even with a 1m grid. This was approximated for by lowering a 1m width along the kerb line by 0.1m
- **Stormwater Asset Data:** Updated pit and pipe data supplied by Council (Table 1) was included. A comparison with the pit and pipe data used in the 2014 Flood Study indicated only minor changes (refer Appendix B and C). Additional pits and pipes were provided in the update but the majority of these were in the new commercial / light industrial subdivision off Cawarra Road, Caringbah. Very few additional pipes were found in the existing urban areas, and these were generally < 500mm diameter and in the upper part of the catchment. Some pipe sizes were changed in the update as well as additional pits provided but these changes were minor and provide no significant change to the overall capacity of the pit and pipe network. There was also no significant change to the location of the pits.

Table 1: Size of Surveyed Culverts (2019) in Study Area

Pipe		Rectangular	
Total	1947	Total	166
<0.45m	936	<0.45m	29
0.45-0.6m	384	0.45-0.6m	16
0.6-1.2m	526	0.6-1.2m	67
1.2-1.8m	94	1.2-1.8m	32
>1.8m	7	>1.8m	22

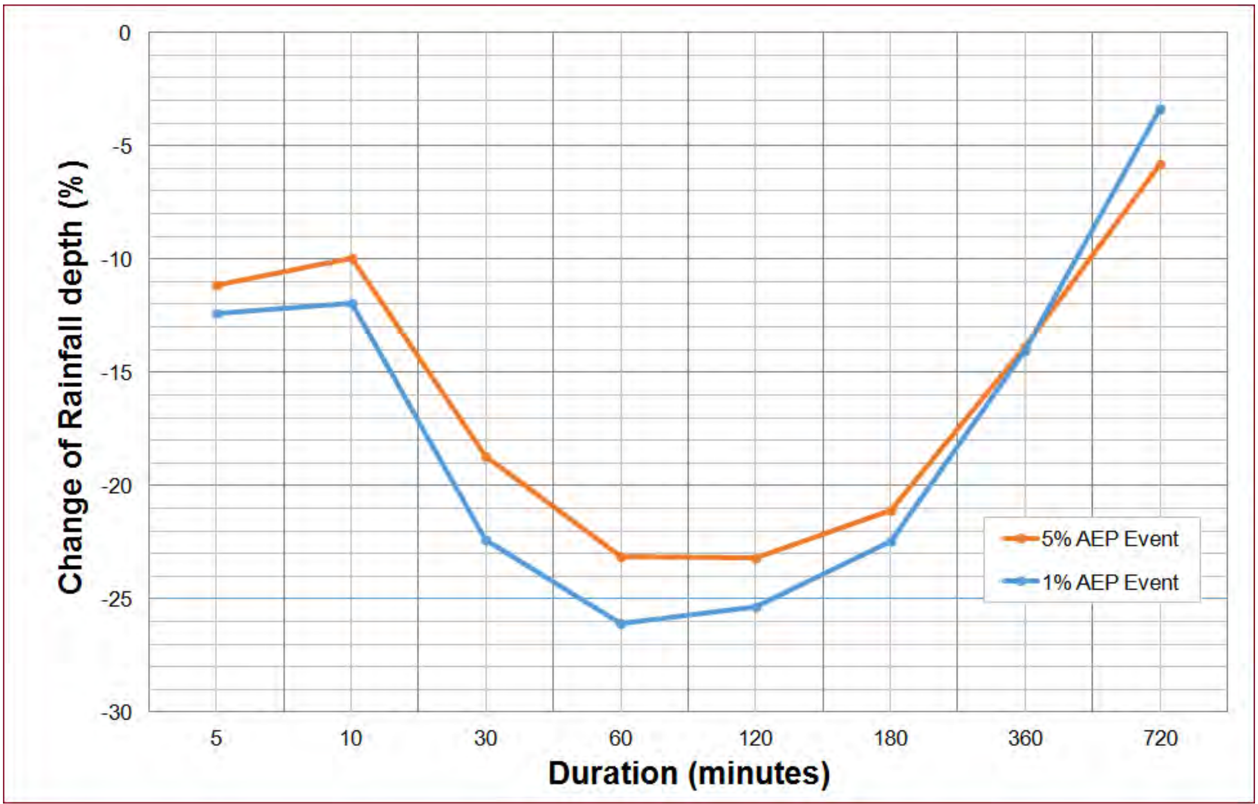
- **Redevelopment in the Catchment:** This included: the post 2014 upgrading of Captain Cook Drive adjacent to Cronulla Golf Course; the assumed final design of the approved residential developments and road works at the football ground; the planned upgrading of the football ground itself and of Captain Cook Drive between Woolooware Road and Gannons Road; earthworks within Cronulla Golf Course and on the Shearwater Estate; construction of noise walls along Captain Cook Drive adjacent to the former Toyota site in 2018/2019; widening of the Gannons Road rail overbridge in mid-2019; earthworks and construction of buildings on the commercial / light industrial site on Wurrook Circuit off Cawarra Road; revision of building outlines based on updated survey.
- **Australian Rainfall and Runoff:** The hydrology was updated to comply with ARR 2019 (Reference 4 and Reference 5) rather than ARR 1987 (Reference 3) (refer Appendix F for further details). Table 2 indicates the ARR 2019 rainfall data for the catchment and Diagram 2 indicates the change in rainfall depth between the ARR 1987 and ARR 2019 rainfall data sets for the catchment. The following are noted:
    - there is an overall decrease in design rainfall intensities for the catchment for all durations.
    - the decrease in design intensities is much higher (decreases up to 26%) for durations from 30 minutes to 180 (this is typically the storm durations that produces flooding in the Woolooware Bay catchment).

- durations of 720 minutes are less than 10% lower than ARR 1987.
- a significant change is that the volume of rainfall and likely flood volumes (affected by loss rates) are reduced with the revised ARR 2019 rainfall data.

Table 2: BoM ARR 2019 Rainfall Depths

Duration	Annual Exceedance Probability (AEP)					
	50%	20%	10%	5%	2%	1%
10 min	14	18	21	24	28	31
15 min	17	23	27	30	35	38
20 min	20	26	30	35	40	44
25 min	22	29	34	38	44	48
30 min	24	31	36	41	47	52
45 min	28	37	42	48	56	61
1 hour	31	41	47	54	62	69
1.5 hour	36	47	55	62	72	80
2 hour	40	52	61	70	81	90
3 hour	47	62	72	82	96	107
4.5 hour	54	72	85	98	115	128
6 hour	61	82	97	112	131	147
9 hour	72	98	116	135	160	180

Diagram 2: Change in Intensity for 1% AEP and 5 % AEP 2019 v 1987 Rainfall Data



- **Design Ocean Levels:** The design ocean levels adopted in the 2014 Flood Study are shown in Table 3 together with the adopted co-incidence of ocean and rainfall events shown on Table 4. As part of the present study the design ocean levels have been amended in accordance with advice from Sutherland Shire Council to make them the same as adopted in similar adjoining flood studies (as shown in Table 3). It is acknowledged that a multitude of combinations of ocean / rainfall conditions can be used to create a given design flood event and there is no technical basis for stating that one scenario is necessarily more correct that any other.

Table 3: Adopted Design Ocean Levels

AEP	Peak Level (mAHD) Those adopted in Reference 1 are shown in blue and those adopted for the present study are shown in red.
20%	1.30 1.1
10%	1.34 1.3
5%	1.38 1.5
2%	1.42 1.6
1%	1.45 1.7
0.5%	1.48 1.8
0.2%	n/a 1.9
PMF	1.50 2.4

Table 4: Adopted Co-incidence of Ocean and Rainfall Events

OCEAN Envelope		DESIGN FLOOD EVENT (AEP)	RAINFALL Envelope	
Peak Design Ocean Event (AEP) and level (mAHD)	Co incident Design Rainfall Event (AEP)		Design Rainfall Event (AEP)	Co incident Design Ocean Event (AEP) and level (mAHD)
PMF	1%	**Extreme/PMF**	PMF	1%
0.2%	5%	**0.2%**	0.2%	5%
0.5%	5%	**0.5%**	0.5%	5%
1%	5%	**1%**	1%	5%
2%	5%	**2%**	2%	5%
5%	5%	**5%**	5%	5%
10%	10%	**10%**	10%	10%
20%	20%	**20%**	20%	20%

3.3. Comparison of Peak Flood Level Results

Figure 4 provides a comparison of peak 1% AEP flood levels produced using ARR 2019 (also including the TUFLOW model update - refer Section 3.2) and the 2014 Flood Study results using ARR 1987 methodologies. The differences between peak flood levels are generally within +/- 0.2m in the upper catchment. The results indicate:

- in the lower part of the catchment and on the two golf courses there is little change in peak levels.
- there are some significant areas with reduction in peak levels near Kirkwood Road and Berry Street, Cronulla; in the small open channel between Elouera Road and Wyanbah Road, Cronulla and west of the new commercial / light industrial subdivision off Cawarra Road, Caringbah.
- there are also many areas of isolated reduction in flood levels or now no longer flooded.

3.4. Conclusions of Flood Modelling Update

The outcomes of the revision of the modelling undertaken as part of the present study are provided in Appendix B and C and should be adopted rather than those in the 2014 Flood Study.

3.5. Description of Flooding

Flooding in the catchment is documented in Appendix B which provides a range of maps describing the peak flood levels, depths, velocities and various other flooding characteristics. In frequent events (say up to an event that occurs on average every two years), in the upper and middle parts of the catchment runoff is largely contained in Council's pit and pipe and road network (kerbs and gutters) infrastructure. In rarer and thus larger events, the capacity of the infrastructure is exceeded, and runoff occurs through private property and outside the gutters. This type of flooding is termed overland flooding as apart from the above infrastructure there is no open channel system.

Within the two golf courses there are open channels and water bodies which are overtopped in events which occur several times a year.

There are several areas (termed hotspots) where flooding occurs more frequent, and these are documented in Section 7.5.

Appendix B and Appendix C provides details of the sensitivity of the depth and extent of flooding to sea level rise, rainfall increases due to climate change, blockage of pits and pipes due to sedimentation or debris. Appendix C also provides a comparison of the results from the 2014 Flood Study and the changes adopted in the present study.

3.6. Flood Function and Hazard Categorisation

The NSW Government's Floodplain Development Manual 2005 (Reference 2) defines three hydraulic categories which could be applied to the study area, namely floodway, flood storage or flood fringe.

Floodways
"those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels."

***Flood storage* areas**
"*those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.*"

Flood fringe

"the remaining area of flood prone land after floodway and flood storage areas have been defined"

There is no precise definition of flood storage and flood fringe or accepted approach to differentiate between the two areas. In the 2014 Woolooware Bay Flood Study hydraulic categorisation was defined according to the following approach, namely:

<u>Floodway</u> = *Velocity * Depth > 0.25m²/s AND Velocity > 0.25m/s OR Velocity > 1m/s*

The remainder of the floodplain outside the Floodway becomes either Flood Storage or Flood Fringe. Flood Storage was defined as the land outside the Floodway if the depth is greater than 0.3m and Flood Fringe if the depth is less than 0.3m. As noted in Reference 4 *"it is impossible to provide explicitly quantitative criteria for defining floodways and flood storage areas, as the significance of such areas is site specific"*.

Hydraulic classification figures are provided in Appendix B.

The Flood Study defined provisional flood hazard categories in accordance with the NSW Floodplain Development Manual (Reference 2). Provisional hazards only take account of the hydraulic aspects of flood hazard; depth and velocity (Diagram 3), while true hazard takes into account additional factors such as size of flood, effective warning time, flood readiness, rate of rise of floodwaters, duration of flooding, evacuation problems, effective flood access, type of development within the floodplain, complexity of the stream network and the inter-relationship between flows.

Diagram 3: Provisional Hydraulic Hazard Categories

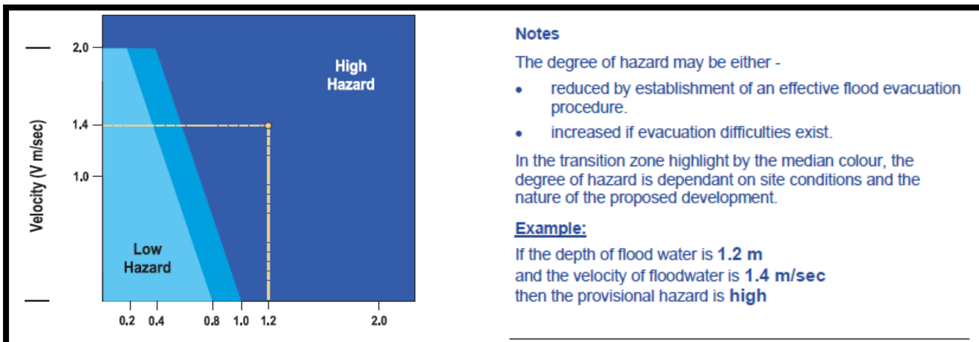


FIGURE L2 - Provisional Hydraulic Hazard Categories

Extracted from The Floodplain Development Manual (Reference 2)

The 2014 Woolooware Bay Flood Study established high and low provisional hazard areas for the 5% and 1% AEP events and the PMF in accordance with the NSW Floodplain Development Manual (Reference 2).

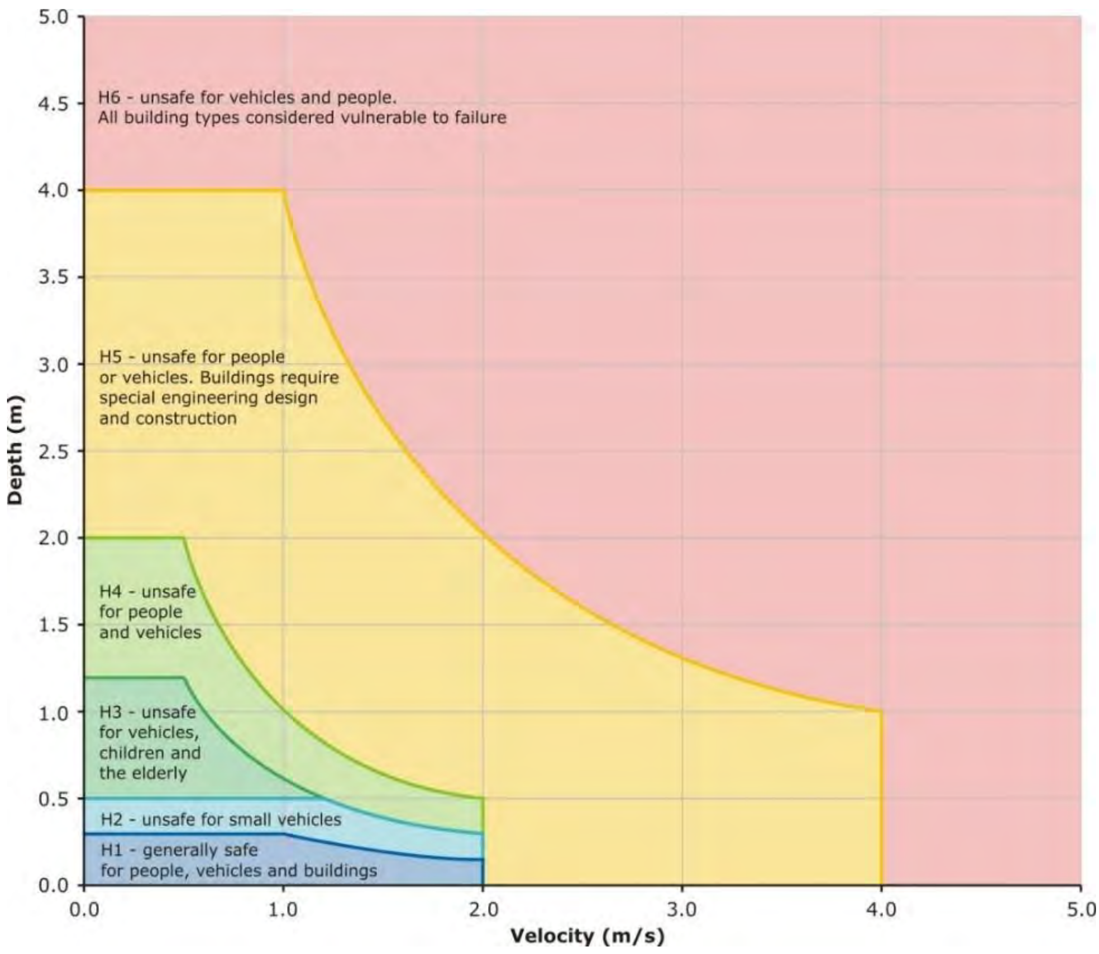
In recent years there has been several developments in the classification of hazard. *Managing the floodplain: a guide to best practice in flood risk management in Australia* (Reference 6) provides revised hazard classifications. These add clarity to the description of hazard categories and what they mean in practice and have been adopted in this FRMS&P.

The hazard classifications are divided into six categories (Diagram 4) which indicate the restrictions on people, buildings, and vehicles:

- H1 - Generally safe for vehicles, people, and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles, children, and the elderly.
- H4 - Unsafe for people and vehicles.
- H5 - Unsafe for people or vehicles. Buildings require special engineering design and construction, and
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

Appendix B provides the hazard classifications based on the H1 – H6 delineations for the ARR 2019, 5%, 1% and 0.2% AEP events as well as the PMF event.

Diagram 4: Hazard Classifications (Reference 6)



The 2014 Woolooware Bay Flood Study also considered the effect of other factors to be considered in determining the “true” hazard such as size of flood, effective warning time, flood readiness, rate of rise of floodwaters, depth and velocity of flood waters, duration of flooding, evacuation problems, effective flood access, type of development within the floodplain, complexity of the stream network and the inter-relationship between flows. The classification is qualitative based on several factors as listed in Table 5 and has been reviewed as part of the present study with comments also shown.

Table 5: Factors Influencing Hazard Classification

Criteria	Weighting Factor	Comment
Size of the Flood	Medium	In the more frequent small flood events there is little inundation that would cause significant hardship and inconvenience to many residents. In larger floods the extent of inundation and affectation are increased but not significantly.
Flood Awareness of the Community	Medium	Residents have experienced a number of floods but these are relatively minor floods which had little impact on their properties. Thus, residents will have a low level of awareness of the impacts of large flood events having not experienced any and no realisation that such floods can happen in urban areas.
Depth and Velocity of Floodwaters	Low	There are few properties which experience high depths and velocities that may potentially cause structural damage to buildings and pose a significant risk to life.
Effective Warning and Evacuation Times	High	Potentially there will be no warning time except from residents observing flooding in the street or property as it occurs.
Evacuation Difficulties	Medium	For most residents, evacuation by road will be possible, however it is probably safer to stay in the building as there are risks outside due to wind, heavy rain or associated issues.
Rate of Rise of Floodwaters	High	The rate of rise of floodwaters is very fast as the catchment is relatively small. Flood peaks on each flowpath may occur at different times or in unison and the rate of rise and severity of an individual event will not always be predictable from the total rainfall at a given location.
Duration of Flooding	Low	The duration of inundation will generally be less than 1 hour and shorter in the upper parts.
Effective Flood Access	Low	For most of the flood affected buildings there is access to high ground and few buildings become isolated.
Additional concerns such as bank erosion, debris, wind wave action, sewage overflows	Medium	Erosion or scouring are unlikely to be of concern except within the golf courses. Debris may be a factor and may contact buildings or residents, particularly in areas of higher depths and velocities near the main flowpaths. Wave action (from wind or vehicle action) and sewage overflows are contributory but minor factors.
Provision of Services	Low	In a large flood it is likely that services will be cut but this will likely be for only a few hours. Possibly some sewer overflow may occur.

In summary the assessment of all factors considered in determining the “true” hazard indicates that the hydraulic hazard categorisation indicated in Diagram 4 will not change to any significant extent.

4. COMMUNITY AND STAKEHOLDER CONSULTATION

4.1. Overview

Consultation is an important element of the floodplain risk management process ultimately facilitating community engagement and acceptance of the overall project. During the Flood Study, community consultation was undertaken to assess the flood experience of the community and gather additional data. Further consultation has also been undertaken as part of the FRMS&P.

Final community consultation proposed is in the form of public exhibition of the draft report.

One of the central objectives of the FRMS&P process is to actively engage with the community and stakeholders throughout the process to achieve the following key outcomes:

- Inform the community about the current study.
- Identify community concerns regarding flooding.
- Gather ideas and information on potential management options for the floodplain.
- Seek feedback on recommended options via public exhibition.

“Community” refers to government (both state and local departments), business, industry, local professionals, and the public. Consultation with the community is an important element of the FRMS&P process facilitating community engagement, building confidence in flood modelling tools, and leading to acceptance and ownership of the overall project.

Consultation during the preparation of the FRMS&P was undertaken primarily with the Sutherland Shire Floodplain Management Committee as well as staff from SES and DPIE. An online workshop was held on 23 September 2021 with several local consulting engineers who provided valuable feedback on their experience with the implementation of flood-related development controls as well as the proposed updates to DCP Chapter 40.

Several community engagement methods were undertaken during the four-week public exhibition of the draft FRMS&P report in December 2021. This included uploading of the draft FRMS&P report to Council’s “Join the Conversation” website together with supporting documents, photographs of flooding, frequently asked questions, a summary brochure and list of survey questions. Where applicable, Council officers responded to individual questions and prepared a summary of all enquiries.

Appendix G provides a more detailed summary of the public consultation program prepared by Council.

4.2. Floodplain Risk Management Committee

The process of managing flood risk in the Woolooware Bay catchment is assisted by the Sutherland Shire Floodplain Risk Management Committee. The committee is made up of Councillors, Council staff, NSW Government Agencies, and local community representatives.

The Committee provides a forum for discussing differing viewpoints within the study area, identifying management measures, and considering and making recommendations to Council on appropriate measures and controls.

The Committee met on three occasions over the course of the FRMS&P project during which it considered the results of the flood model update, the process for adding flood notations to S10.7 planning certificates of affected properties, potential FRM options and the draft FRMS&P report.

4.3. Stakeholder Consultation

Staff from DPIE, SES and local consulting engineers were consulted during the project. DPIE staff provided input on the feasibility of FRM options, the potential for gaining grant funding and the application of the NSW flood prone land package.

The SES is the legislated combat agency for floods in NSW and is responsible for the control of flood response operations. It maintains a flood intelligence system for key flood warning gauges in NSW and develops specific flood emergency plans for LGAs which are subject to flooding. The SES were consulted on flood emergency response planning, options for raising community flood awareness, and options for horizontal and vertical evacuation.

Local consulting engineers provided industry feedback on the proposed updates to Council's DCP and provide greater guidance on development approval pathways and the application of flood-related development controls.

5. IMPACTS OF FLOODING

5.1. Overview

The damages caused by flooding can be separated into three broad categories: economic, social and environmental.

Economic impacts are quantified based on inundation of private property. There are also economic costs to government authorities in terms of clean-up / renewal of flood affected assets, assistance to residents in clean-up (e.g., waste removal), disaster relief payments, etc, however these have not been quantified for this study. Social impacts are considered through intangible damages associated with property inundation as well as inundation of roads causing traffic disruption. Environmental impacts of flooding are important to consider given the catchment drains to the aquatic reserve in Woolooware Bay that surrounds the RAMSAR listed Towra Point wetlands.

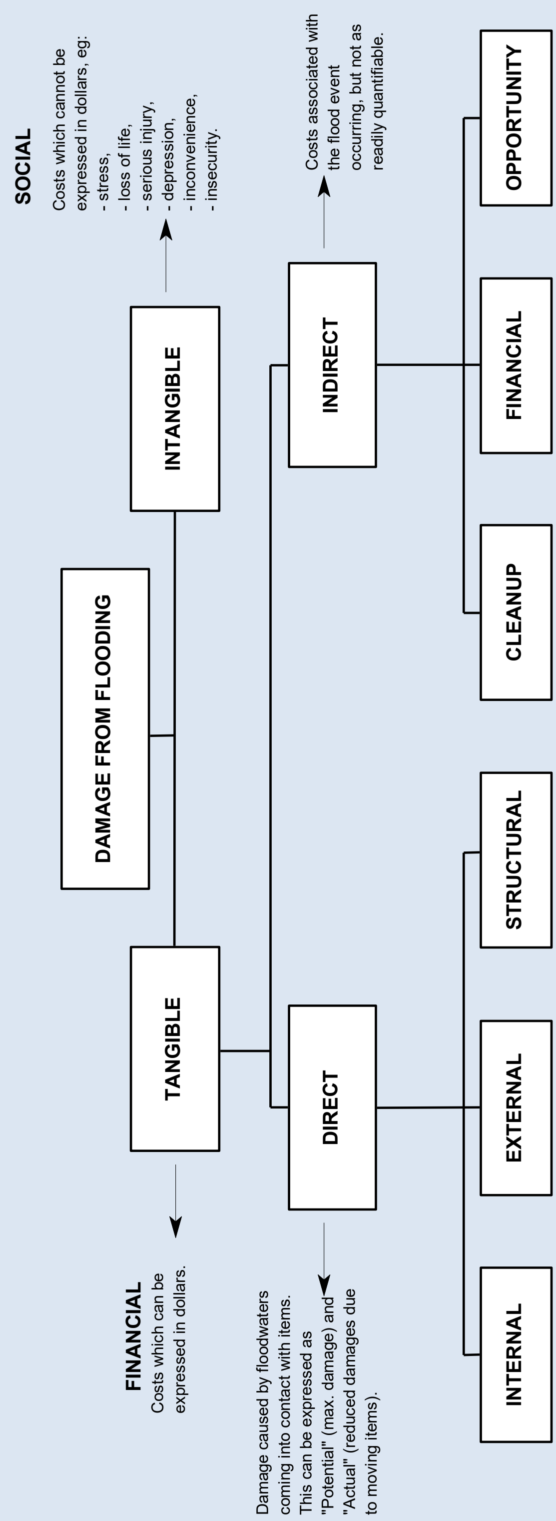
5.2. Flood Damages Assessment

The impact of flooding can be quantified through the calculation of flood damages. Flood damage calculations do not include all impacts associated with flooding (for example it does not include worry, risk to life or injury). They do, however, provide a basis for assessing the economic loss of flooding and a non-subjective means of assessing the merit of flood mitigation works such as retarding basins, levees, drainage enhancement etc. The quantification of flood damages is an important part of the floodplain risk management process. By quantifying flood damages for a range of design events, appropriate cost-effective management measures can be analysed in terms of their benefits (reduction in damages) versus the cost of implementation. The cost of damage and the degree of disruption to the community caused by flooding depends upon many factors including:

- The magnitude (depth, velocity, and duration) of the flood.
- Land use and susceptibility to damages.
- Awareness of the community to flooding.
- Effective warning time.
- The availability of an evacuation plan or damage minimisation program.
- Physical factors such as failure of services (sewerage), flood borne debris, sedimentation.
- The types of assets and infrastructure affected.

The estimation of flood damages tends to focus on the physical impact of damages on the human environment but there is also a need to consider the ecological cost and benefits associated with flooding. Flood damages can be defined as being tangible or intangible. Tangible damages are those for which a monetary value can be easily assigned, while intangible damages are those to which a monetary value cannot easily be attributed. Types of flood damages are shown in Table 6.

Table 6: Categories of Flood Damages



	INTERNAL	EXTERNAL	STRUCTURAL	CLEANUP	FINANCIAL	OPPORTUNITY
RESIDENTIAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Laundries, Caravans, Sheds, Tools, Gardens, Fences	Physical Damage to Buildings: Gyprock, Cupboards, Scour of Footings, Houses becoming buoyant (floating off footings)	Clean Carpets, Walls, Clothes; Re-instate Furniture; Remove Mud and Debris	Loss of wages, Living costs (temporary accomodation and food), Time to repair/replace damaged items	Not Applicable
RURAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Sheds (stables/barns), Machinery, Tools, Fences, Feed storage, Saddles, Crops &/or Stock, Irrigation Systems	Physical Damage to Structures: Damage to Homestead, Sheds, Access tracks, Protection levees	Clean Homestead and Out-buildings; Remove Debris; Dispose of affected crops &/or stock	Loss of Farm Production and Income, Re-instatement of Pastures, Supplementary feeding of stock (by hand or outside agistment), Stock movement/ transport, Living costs (temporary accomodation and food)	Sowing or harvesting of Crops, Sale of Stock (at depreciated value or dependent on market influences)
COMMERCIAL	Contents of Buildings: Products, Stock, Fittings, Tools, Machinery, Raw Materials	External Items: Vehicles, Machinery, Display, Raw Materials/Stockpiles, Fences	Physical Damage to Buildings	Dispose of damaged products, stock, materials; Cleaning and Re-instatement	Loss of Productivity and Income, Bank Interest Charges	Loss of existing &/or Potential Trade
PUBLIC AUTHORITIES	Contents of Public Buildings and Facilities	Public Property and Facilities: Parks, Signs, Machinery, Equipment	Physical Damage to Infrastructure: Electricity, Water, Telephone, Gas, Road & Rail Transport Links	Remove Mud & Debris from Facilities, Public & Private Property Repairs (temporary & permanent)	Disruption of Services, Community Service Relief Grants	Provision of Public Service

5.3. Tangible Flood Damages

Tangible flood damages are comprised of two basic categories; direct and indirect damages (refer Table 6). Direct damages are caused by floodwaters wetting goods, structures and possessions thereby damaging them and resulting in either costs to replace or repair or in a reduction to their value. Direct damages are further classified as either internal (damage to the contents of a building including carpets, furniture), structural (referring to the structural fabric of a building such as foundations, walls, floors, windows) or external (damage to all items outside the building such as cars, garages). Indirect damages are the additional financial losses caused by the flood for example the cost of temporary accommodation, loss of wages by employees, etc.

Given the variability of flooding and property and content values, the total likely damages figure in any given flood event is useful to get a feel for the magnitude of the flood problem, however it is of limited value for absolute economic evaluation. Flood damage estimates are also useful when studying the economic effectiveness of proposed mitigation options, however difficulties arise when trying to assess intangible damages such as loss of life or inconvenience. Understanding the total damages prevented over the life of the option in relation to current damages, or to an alternative option, can assist in the decision-making process.

The standard way of expressing flood damages is in terms of average annual damages (AAD). AAD represents the equivalent average damages that would be experienced by the community on an annual basis, by considering the probability of a flood occurrence. This means the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods.

To quantify the damages caused by inundation for existing development, floor level survey and estimates were made (see Section 3.1). This was used in conjunction with modelled flood level information from the updated flood information (Appendix B) to calculate damages. Damage calculations were carried out for all properties within the PMF extent.

The damages were calculated using height-damage curves which relate the depth of water above the floor with tangible damages. Each component of tangible damages is allocated a maximum value and a maximum depth at which this value occurs. Any flood depths greater than this allocated value do not incur additional damages as it is assumed that, by this level, all potential damages have already occurred.

Damages were calculated for residential and commercial/industrial properties, discussed separately below. This flood damages estimate does not include the cost of restoring or maintaining public services and infrastructure. It should be noted that damages calculations do not consider flood damages to any basements or cellars, hence where properties have basements, damages can be underestimated.

For mainstream flooding areas (Georges River) determination of the magnitude of the event which first overtops the floor level is straightforward and accurate. However, in overland flow areas the assessment is more complex and thus less accurate for the following reasons.

- The shallow depths of inundation (less than 0.5m) mean that a small error in the modelling process (say 0.2m) represents a significant change in the AEP of the flood compared to areas where the flood depths are much greater.
- Small changes in ground level (accuracy of ALS) or local obstructions (garden borders,

small walls etc.) cannot be accurately represented in a catchment wide study and may result in errors in the peak levels.

- If house owners experience past above floor inundation they will generally try and incorporate local mitigation measures (walls, door seals, diversion works) and these are unknown and thus not included in the hydraulic modelling.
- The results from flood modelling are generally more reliable in large floods (say greater than the 5% AEP) than the smaller more frequent events.

5.3.1. Residential Properties

Residential properties suffer damages from flooding in several ways. Direct damages include loss of property contents and/or damage to the structure of the property. Indirect damage costs can be incurred when property occupiers live elsewhere while repairs are being made. A flood damages assessment for residential properties was undertaken for the floor level data obtained by the methods outlined in Section 3.1. A summary of the flood damages assessment is provided in Table 7 with the properties shown on Figure 5.

Table 7: Flood Damages (Residential)

Event	No. Properties Affected	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
50%AEP	297	28	$ 2,920,000	24	$ 10,000
20% AEP	354	47	$ 4,310,000	36	$ 12,000
10% AEP	398	57	$ 5,260,000	16	$ 13,000
5% AEP	443	67	$ 6,100,000	9	$ 14,000
2% AEP	553	99	$ 8,470,000	7	$ 15,000
1% AEP	600	105	$ 9,380,000	3	$ 16,000
0.5% AEP	629	118	$ 10,460,000	2	$ 17,000
0.2% AEP	682	137	$ 11,880,000	1	$ 17,000
PMF	1089	416	$ 32,600,000	1	$ 30,000
Average Annual Damages (AAD)			$ 3,010,000		$ 3,000

Table 7 indicates a moderate degree of flood liability for more frequent events with 105 residential properties flooded above floor level in the 1% AEP event. In the PMF there are an estimated 416 residential properties flooded above floor level indicating a significant degree of flood risk and associated flood damages. On average, flooding to residential properties in the Woolooware Bay catchment costs Council and the community approximately $3 million per annum.

5.3.2. Non-Residential – Commercial and Industrial

Non-residential land uses in the study area are predominantly situated on land bordering Woolooware Bay (old Toyota site, football grounds, Taren Point, Woolooware and Cronulla golf courses).

Non-residential properties are affected either directly by flood damage or indirectly by loss of business due to restricted customer and/or employee access. Costs vary significantly depending on the type of activity.

- Type of business – stock based or not, costs of damages to goods.
- How stock and equipment is stored or located in the building.
- Duration of flooding – affects how long a business may be closed for not just whether the business itself is closed, but when access to it is restored.
- Ability to move stock or assets before onset of flooding. Some large machinery will not be able to be moved and in other instances there may be insufficient warning time to move stock to dry locations.
- Ability to transfer business to a temporary location.

A summary of the flood damages assessment for commercial and industrial properties is provided in Table 8 with the properties shown on Figure 5. Table 8 indicates relatively limited flood liability for non-residential properties.

Table 8: Flood Damages (Commercial and Industrial)

Event	No. Properties Affected	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
50%AEP	24	1	$ 280,000	14	$ 12,000
20% AEP	33	3	$ 560,000	26	$ 17,000
10% AEP	44	8	$ 1,240,000	18	$ 28,000
5% AEP	51	12	$ 1,730,000	15	$ 34,000
2% AEP	74	15	$ 2,270,000	12	$ 31,000
1% AEP	78	18	$ 2,710,000	5	$ 35,000
0.5% AEP	88	21	$ 3,160,000	3	$ 36,000
0.2% AEP	104	26	$ 3,810,000	2	$ 37,000
PMF	185	122	$ 16,630,000	4	$ 90,000
Average Annual Damages (AAD)			$ 490,000		$ 3,000

5.3.3. Critical Infrastructure and Vulnerable Facilities

Public sector (non-building) damages include recreational/tourist facilities; water and sewerage supply; gas supply; telephone supply; electricity supply including transmission poles/lines, sub-stations, and underground cables; rail; roads and bridges including traffic lights/signs; and costs to employ emergency services and assist in cleaning up. Public sector damages can contribute a significant proportion to total flood costs but are difficult to accurately calculate or predict.

Costs to Councils from flooding typically comprise.

- Clean-up costs.
- Erosion and siltation.
- Drain cleanout and maintenance.
- Removing fallen trees.
- Inundation of Council buildings.
- Direct damage to roads, bridges, and culverts.
- Removing vehicles washed away.
- Assistance to ratepayers.
- Increases in insurance premiums.

- Closures of streets.
- Loss of working life of road pavements.
- Operational costs following and during flood events.

There are 13 vulnerable properties below the 1% AEP flood extent in the catchment and another 15 properties are within the PMF extent as shown Table 9. The properties are shown on Figure 6.

Table 9: Vulnerable Properties within the Floodplain

Type	Address	Flood Affectation	PMF Hazard	1% AEP Hazard
Local Club	461 Captain Cook Drive	1% AEP and PMF	H6	H5
Local Club	477 Captain Cook Drive	1% AEP and PMF	H6	H5
School	2R Woolooware Road	1% AEP and PMF	H5	H5
Childcare	83 Gannons Road	1% AEP and PMF	H5	H5
Local Club	475 Captain Cook Drive	100y and PMF	H5	H4
Childcare	105 Cawarra Road	1% AEP and PMF	H5	H3
Church	3A Endeavour Road	1% AEP and PMF	H5	H3
School	34 Wills Road	1% AEP and PMF	H5	H2
Aged Care/Assisted Living	31 Sturt Road	1% AEP and PMF	H4	H3
Local Club	1R Harnleigh Avenue	1% AEP and PMF	H3	H2
School	31 Bate Bay Road	1% AEP and PMF	H2	H1
School	123R Cawarra Road	1% AEP and PMF	H1	H1
Medical Centre	156-158 Kingsway	1% AEP and PMF	H1	H1
Childcare	7 Banksia Road	PMF	H1	H0
Aged Care/Assisted Living	163 Kingsway	PMF	H1	H0

Note: The Hazard shown is the highest / peak hazard on the property and it may be only a small part of the land affected. Individual lot information can be obtained from Council.

Flooding to schools, and to similar institutions, would have different impacts depending on the time of day and obviously during school hours the response would be more critical due to the number of persons on the site. It is important that the affected schools have effective flood plans implemented and that the SES have knowledge of all vulnerable properties.

5.3.4. Basement Car Parks

In the last 10+ years there has been an increasing construction of basement car parks for residential (unit and detached housing) and to a lesser extent for commercial buildings. Table 10 indicates basements which possibly may be subject to inundation in the Woolooware Bay catchment.

The inundation of basements represents a significant risk to life as people may become trapped or try and “rescue” vehicles. It is expected that most of these basement car parks will be recent constructions and thus subject to current flood guidelines.

Table 10: Basement Car Parks Possibly Subject to Inundation

Address	Land Type	Address	Land Type
167 Kingsway, Woolooware	R2	231-233 Kingsway, Caringbah	R4
70 Yathong Road, Caringbah	R3	93 Elouera Road, Cronulla	R4
8 Alfred Avenue, Cronulla	R2	19-23 Marlo Road, Cronulla	R4
2A Glandore Street, Woolooware	R2	73-75 Elouera Road, Cronulla	R4
15 Sturt Road, Cronulla	R2	38-42 Hume Road, Cronulla	R4
23 Links Avenue, Cronulla	R3	21-25 Wyanbah Road, Cronulla	R3
25 Links Avenue, Cronulla	R3	239 Kingsway, Caringbah	R4
8 Delagoa Place, Caringbah	R2	3-7 Nerang Road, Cronulla	R4
6 Delagoa Place, Caringbah	R2	50-52 Seaview Street, Cronulla	R4
14 Delagoa Place, Caringbah	R2	34-36 Hume Road, Cronulla	R4
9 Pozieres Street, Cronulla	R2	83-85 Elouera Road, Cronulla	R4
12 Delagoa Place, Caringbah	R2	29 Bando Road, Cronulla	R4
253-261 Kingsway, Caringbah	R4	100-102 Elouera Road, Cronulla	R4
10 Delagoa Place, Caringbah	R2	237 Kingsway, Caringbah	R4
50 Woolooware Road, Woolooware	R2	64 Elouera Road, Cronulla	R4
199 Kingsway, Woolooware	R2	53 Wyanbah Road, Cronulla	R4
21 Ocean Street, Cronulla	R3	247-251 Kingsway, Caringbah	R4
234 Burraneer Bay Road, Caringbah South	R2	241-245 Kingsway, Caringbah	R4
165 Kingsway, Woolooware	R2	56-58 Seaview Street, Cronulla	R4
118 Kingsway, Woolooware	R2	47 Wyanbah Road, Cronulla	R4
109-113 Elouera Road, Cronulla	R4	65-67 Elouera Road, Cronulla	R4
95 Gannons Road, Caringbah South	R2	31-33 Banksia Road, Caringbah	R4
43 Woodward Avenue, Caringbah South	R2	1 Banksia Road, Caringbah	R4
69-71 Elouera Road, Cronulla	R4	235 Kingsway, Caringbah	R4
105-107 Elouera Road, Cronulla	R4	25 Bando Road, Cronulla	R4
2-4 Kurnell Road, Cronulla	R3	90 Elouera Road, Cronulla	R4
240 Kingsway, Caringbah	R3	28 Bando Road, Cronulla	R4
11 Burke Road, Cronulla	R4	96-98 Elouera Road, Cronulla	R4
55 Wyanbah Road, Cronulla	R4	121 Elouera Road, Cronulla	R4
60-62 Elouera Road, Cronulla	R4	89 Elouera Road, Cronulla	R4
3-5 Banksia Road, Caringbah	R4	49 Wyanbah Road, Cronulla	R4
28 Tullimbar Road, Cronulla	R4	2-4 Northumberland Road, Caringbah	IN1
82-84 Elouera Road, Cronulla	R4	2 Wurrook Circuit, Caringbah	B7
35-37 Wyanbah Road, Cronulla	R4	36 Cawarra Road, Caringbah	B7
43-45 Wyanbah Road, Cronulla	R4	23C Dolans Road, Woolooware	R2
51 Wyanbah Road, Cronulla	R4	296-300 Kingsway, Caringbah	B3
		230 Kingsway, Caringbah South	R2

5.4. Intangible Flood Damages

The intangible damages associated with flooding, by their nature, are inherently more difficult to estimate in monetary terms. In addition to the tangible damages discussed previously, additional costs/damages are incurred by residents affected by flooding, such as stress, risk/loss to life, injury, loss of sentimental items, etc. It is not possible to put a monetary value on the intangible damages as they are likely to vary dramatically between each flood (from a negligible amount to several hundred times greater than the tangible damages) and depend on a range of factors such as the size of flood, the individuals affected, and community preparedness. However, it is still important that the consideration of intangible damages is included when considering the impacts of flooding on a community.

Post-flood damages surveys in mainly rural areas (the effect in urban areas such as Woolooware Bay is likely to be much less) have linked flooding to stress, ill-health, and trauma for the residents. For example, the loss of memorabilia, pets and other items without fixed costs and of sentimental value may cause stress and subsequent ill-health. In addition, flooding may affect personal relationships and lead to stress in domestic and work situations. As well as the stress caused during an event (from concern over property damage, risk to life for the individuals or their family, clean up, etc.) many residents in rural areas who have experienced a major flood are fearful of the occurrence of another flood event and the associated damage (this impact is less so in urban areas). The extent of the stress depends on the individual and although most flood victims recover, these effects can lead to a reduction in quality of life for the flood victims.

Flood affectation to many of the critical infrastructure and vulnerable facilities may also result in significant intangible damages. For example, damage to service supply (water, sewage) will affect households as will the temporary closure of schools or childcare facilities as repairs are carried out. The flood affectation to these facilities will not necessarily occur at the site of the facility. Thus, just because the facility is not directly affected by flooding does not mean that flooding will not have a bearing on the facilities activities and the resulting community. For example, with schools, childcare, and aged care the main issue is with access to the facility, and this may be some distance from the building.

With service infrastructure (sewer, water, electricity) the main facility will likely not be directly affected by floodwaters, but the supply will be affected by say fallen trees hitting power lines or closure of the sewer system as floodwaters are entering the system in the flooded area. Many of these affectations to the critical infrastructure and vulnerable facilities are variable and will not necessarily occur in all floods or at the same locations. It is only through review of past floods that the true affectation to critical infrastructure and vulnerable facilities can be addressed. This review should also mean that mitigation or upgrading of the facility can be assessed.

5.5. Road Inundation and Access

Understanding flood access issues is critical to effective evacuation and flood response planning in rural areas but less so in urban areas where the duration of intense rain and flooding is short (say less than 1 hour) and traffic is likely to be stopped at some locations due to storm associated events (flooding, fallen trees, cars stalled, traffic accidents, traffic lights cut). The Flood Study modelled peak flood depths (black) and velocities (red) within the Woolooware Bay catchment which are presented in Table 11 at various road crossing. The locations of these flooded access roads are presented in Figure 1.

Table 11: Flood Depths and Velocities at Road Crossings

ID	Location*	Event Depth (m) and Velocity (m/s)								
	(Figure 1)	50%AEP	20%AEP	10%AEP	5% AEP	2%AEP	1%AEP	0.5%AEP	0.2%AEP	PMF
R1	Captain Cook Dr	0.4 /0.1	0.5 /0.6	0.6 /0.8	0.6 /0.9	0.7 /1	0.8 /1.2	0.8 /1.2	0.8 /1.3	1.6 /1.1
R2	Captain Cook Dr	-	0.4 /1.6	0.5 /1.6	0.5 /1.6	0.6 /1.6	0.6 /1.7	0.7 /1.7	0.7 /1.7	1.2 /0.8
R3	Captain Cook Dr	-	0.2 /0.8	0.3 /1	0.3 /1	0.4 /1.1	0.5 /1.1	0.5 /1.2	0.5 /1.2	1 /1.3
R4	Endeavour Rd	0.3 /0.4	0.4 /0.6	0.5 /0.8	0.6 /0.9	0.6 /1	0.7 /1.1	0.7 /1.2	0.8 /1.3	1.3 /2
R5	Endeavour Rd	0.3 /0.7	0.3 /0.6	0.4 /0.5	0.4 /0.6	0.5 /0.6	0.5 /0.5	0.6 /0.6	0.6 /0.6	1.3 /1.1
R6	Northumberland Rd	0.3 /0.3	0.3 /0.3	0.4 /0.2	0.5 /0.2	0.5 /0.3	0.6 /0.2	0.6 /0.2	0.7 /0.2	1.1 /0.3
R7	Captain Cook Dr	-	-	-	-	-	-	-	-	0.2 /0.8
R8	Captain Cook Dr	-	-	-	-	-	-	-	-	0.3 /2.5
R9	Woolooware Rd	0.2 /0.6	0.3 /0.8	0.3 /0.9	0.3 /1	0.4 /1	0.4 /1	0.5 /1	0.5 /1.1	0.8 /1.5
R10	Edinburgh Cl	0.2 /0.3	0.2 /0.3	0.2 /0.4	0.3 /0.4	0.3 /0.5	0.3 /0.5	0.3 /0.5	0.4 /0.6	0.6 /1.4
R11	Wills Rd	0.2 /0.5	0.2 /0.5	0.2 /0.5	0.3 /0.5	0.3 /0.5	0.3 /0.5	0.3 /0.5	0.3 /0.5	0.5 /0.5
R12	Burke Rd	0.1 /0.3	0.2 /0.3	0.2 /0.5	0.3 /0.5	0.3 /0.5	0.4 /0.5	0.4 /0.5	0.5 /0.5	1.4 /0.9
R13	Marlo Rd	0.3 /0.2	0.4 /0.3	0.5 /0.3	0.6 /0.3	0.7 /0.3	0.8 /0.3	0.9 /0.3	1 /0.3	1.8 /0.4
R14	Bando Rd	0.1 /0.4	0.1 /0.4	0.2 /0.5	0.3 /0.5	0.3 /0.5	0.4 /0.5	0.4 /0.5	0.4 /0.5	1.1 /0.6
R15	Tullimbar Rd	0.1 /0.4	0.2 /0.2	0.2 /0.2	0.2 /0.2	0.3 /0.1	0.3 /0.2	0.3 /0.2	0.3 /0.2	0.8 /0.2
R16	Elouera Rd	0.3 /0.7	0.3 /0.8	0.4 /0.8	0.4 /0.8	0.4 /0.7	0.4 /0.8	0.4 /0.8	0.5 /0.8	0.6 /0.7
R17	Gannons Rd	0.3 /2.2	0.4 /2.2	0.5 /2.1	0.6 /2.2	0.8 /2.2	0.9 /2.1	1 /2.1	1.1 /2.1	2.2 /2.4
R18	Holly St	0.3 /0.3	0.4 /0.3	0.4 /0.4	0.4 /0.4	0.4 /0.4	0.5 /0.4	0.5 /0.4	0.5 /0.5	0.8 /1.1
R19	Caringbah Rd	0.2 /1.4	0.2 /1.7	0.3 /1.9	0.3 /1.9	0.4 /2	0.5 /2.1	0.5 /2.1	0.5 /2.3	0.8 /3.4
R20	Gannons Rd	0.3 /0.9	0.4 /0.9	0.4 /1	0.4 /1.1	0.5 /1.2	0.5 /1.2	0.5 /1.2	0.5 /1.2	0.7 /2.3
R21	Kingsway	0.4 /0.3	0.4 /0.4	0.4 /0.3	0.5 /0.3	0.5 /0.3	0.5 /0.3	0.5 /0.3	0.5 /0.4	0.6 /0.6
R22	Denman Ave	0.6 /0.4	0.7 /0.4	0.7 /0.4	0.7 /0.4	0.8 /0.4	0.8 /0.5	0.8 /0.6	0.9 /0.6	1.2 /2.2
R23	Sturt Rd	0.2 /0.4	0.3 /0.4	0.3 /0.5	0.3 /0.5	0.4 /0.4	0.4 /0.5	0.4 /0.5	0.4 /0.5	0.4 /0.7
R24	Taronga Parade	0.1 /1.2	0.2 /1.6	0.2 /1.7	0.2 /1.8	0.2 /2.1	0.2 /2.1	0.3 /2.2	0.3 /2.2	0.6 /3.2
R25	Yathong Rd	0.2 /0.8	0.2 /1.1	0.3 /1.3	0.3 /1.4	0.3 /1.8	0.3 /2	0.3 /2.1	0.3 /2.2	0.6 /3.4
R26	Yathong Rd	0.1 /1	0.2 /1.1	0.2 /1.2	0.3 /1.3	0.3 /1.5	0.4 /1.7	0.4 /1.8	0.4 /2	0.8 /2.6
R27	Yathong Rd	0.2 /1	0.2 /1.3	0.3 /1.5	0.3 /1.5	0.4 /1.6	0.5 /1.8	0.5 /1.9	0.5 /2	1 /2.6
R28	Raleigh Ave	0.3 /0.4	0.3 /0.4	0.4 /0.4	0.4 /0.4	0.5 /0.5	0.6 /0.5	0.6 /0.5	0.7 /0.5	1.1 /0.7
R29	Burleigh Ave	0.2 /0.3	0.3 /0.4	0.4 /0.4	0.4 /0.5	0.5 /0.5	0.5 /0.5	0.6 /0.5	0.6 /0.5	1 /1.1
R30	Meta St	0.3 /0.5	0.4 /0.4	0.5 /0.4	0.5 /0.4	0.5 /0.5	0.5 /0.7	0.6 /0.8	0.6 /0.9	1 /1.9
R31	Adventure Pl	0.4 /0.4	0.5 /0.4	0.5 /0.3	0.6 /0.3	0.6 /0.3	0.7 /0.4	0.7 /0.4	0.7 /0.3	1.1 /0.3
R32	Northumberland Rd	0.2 /0.4	0.3 /0.4	0.3 /0.3	0.3 /0.3	0.4 /0.3	0.4 /0.3	0.4 /0.3	0.4 /0.3	0.8 /0.5
R33	Mangrove Ln	0.3 /0.4	0.3 /0.4	0.3 /0.4	0.3 /0.4	0.4 /0.4	0.4 /0.4	0.4 /0.4	0.4 /0.4	0.5 /0.6
R34	Gannons Rd	0.1 /0.9	0.1 /1	0.1 /1.1	0.2 /1.1	0.2 /1.3	0.2 /1.3	0.2 /1.4	0.2 /1.5	0.6 /1.7
R35	Captain Cook Dr	0.5 /0.5	0.6 /0.6	0.7 /0.7	0.8 /0.7	0.9 /0.7	0.9 /0.7	1 /0.7	1 /0.8	1.4 /0.9
R36	Captain Cook Dr	0.6 /0.2	0.7 /0.2	0.7 /0.2	0.8 /0.2	0.9 /0.2	0.9 /0.2	1 /0.2	1 /0.2	1.4 /0.5

Research undertaken for the revision of ARR 2019 shows that vehicles can become unstable in shallow depths of floodwaters (~0.1 m) if velocities approach 3 m/s. Small cars can float in still water depths of only 0.3 m (Reference 7).

Information about the depths and velocities of road inundation and likely timing of road closures can aid flood response planning in rural areas to ensure that evacuation and or emergency access occurs in a timely fashion. However, in urban areas it is of less value as traffic may already be stopped for other storm related actions.

5.6. Environmental Impacts of Flooding

The key points regarding the environmental impacts of flooding are:

- Floodwaters will carry large quantities of suspended sediment and other pollutants, primarily derived from the catchment.
- Floodwaters may also convey hazardous chemicals (oils, paints, etc) that could be stored on flood-affected properties in the Taren Point industrial area.
- Although pollutant loads during floods will likely be high, concentrations could be low due to dilution both by overland flows and in Woolooware Bay. Notwithstanding, the Towra Point Aquatic Reserve will be sensitive to pollution events.
- More than 90% of the annual pollutant load is conveyed in events that occur several times a year. Although individual floods will convey a large pollutant load, the fact they are infrequent means that their contribution to the total annual pollutant load is minor.
- The environmental impact of flooding is best minimised by ensuring that flowpaths are stabilised (e.g., channels protected from erosion) and kept free of potential polluting material such as stockpiled soil. Hazardous goods on flood-affected private properties should either be removed from the floodplain or stored above floodwaters.

6. LANDUSE PLANNING FRAMEWORK

This section provides a general overview of the current planning instruments and legislation, however a detailed review of the documents relevant to the study area and LGA was undertaken by GLN Planning for this FRMS&P and their report is included in Appendix D. GLN's report indicated that the key benefits that planning can provide within the suite of strategies delivered by a FRMS&P are:

- Providing guidance at the strategic planning stage as to where different types of development should occur based on FRM considerations, regarding potential and acceptable mitigation measures.
- Providing development controls to minimise the risk to people, private property, and public infrastructure where development is planned to occur within the floodplain.
- To ensure that the communication of flood risk, as may be interpreted by the community through planning documents, is easily understood and cannot be misinterpreted. Planning documents typically deal with where flood related planning controls apply rather than where flood risks apply.

6.1. National Provisions – Building Code of Australia

The Building Code of Australia (BCA) is a uniform set of technical provisions for the design and construction of buildings and other structures throughout Australia. The goals of the BCA are to enable the achievement and maintenance of acceptable standards of structural sufficiency, safety, health and amenity for the benefit of the community now and in the future.

The BCA contains requirements to ensure new buildings and structures and, subject to State and Territory legislation, alterations and additions to existing buildings located in flood hazard areas do not collapse when subjected to flood actions resulting from the defined flood event. The Standard provides additional requirements for buildings in flood hazard areas consistent with the objectives of the BCA which primarily aim to protect the lives of occupants of those buildings in events up to and including the defined flood event (in NSW this is generally taken as the 1% AEP event). Flood hazard areas are identified by the relevant State/Territory or Local Government authority.

The BCA is produced and maintained by the Australian Building Codes Board, and given legal effect through the *Building Act 1975,* which in turn is given legal effect by building regulatory legislation in each State and Territory. Any provision of the BCA may be overridden by, or subject to, State or Territory legislation. The BCA must therefore be read in conjunction with that legislation.

6.2. State Provisions

6.2.1. EP&A Act 1979

The NSW Environmental Planning and Assessment Act 1979 (EP&A Act) provides the framework for regulating and protecting the environment and controlling development.

6.2.2. Ministerial Direction 4.3

Pursuant to Section 117(2) of the EP&A Act, the Minister has directed that Councils have the responsibility to facilitate the implementation of the NSW Government's Flood Prone Land Policy. The objectives of Direction 4.3 are:

(a) to ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005, and

(b) to ensure that the provisions of an LEP on flood prone land is commensurate with flood hazard and includes consideration of the potential flood impacts both on and off the subject land.

Various clauses within Direction 4.3 provide additional legislation in regard to development on the floodplain. This includes restrictions that do not allow for development in the floodway, flood impacts on adjoining properties, and development intensification within the flood planning area.

6.2.3. NSW Flood Prone Land Policy

The primary objectives of the NSW Government's Flood Prone Land Policy are:

- to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone land, and
- to reduce public and private losses resulting from floods whilst utilising ecologically positive methods wherever possible.

The NSW Floodplain Development Manual 2005 (Reference 2) relates to the development of flood prone land for the purposes of Section 733 of the Local Government Act 1993 and incorporates the NSW Flood Prone Land Policy.

The Manual outlines a merits approach based on floodplain management. At the strategic level, this allows for the consideration of social, economic, cultural, ecological and flooding issues to determine strategies for the management of flood risk.

The Manual recognises differences between urban and rural floodplain issues. Although it maintains that the same overall floodplain management approach should apply to both, it recognises that a different emphasis is required to address issues particular to a rural floodplain.

6.2.4. DPIE Flood Prone Land Package July 2021

In July 2021 the Department of Planning, Industry and Environment (DPIE) updated a package of materials relating to the management of flood-prone land. These changes are discussed in Appendix D. The materials are:

- A new planning circular: Considering flooding in land use planning: guidance and statutory requirements (and revoking the existing planning circular PS 07-003).
- A new guideline: Considering Flooding in Land Use Planning (2021) (and revoking the Guideline on Development Controls on Low Flood Risk Areas).

- An amendment to clause 7A of Schedule 4 to the Environmental Planning and Assessment Regulation 2000. The changes will simplify the notation to advise of flood-related development controls up to the flood planning area (clause 7A(1)) or between the flood planning area and the PMF (clause 7A(2)).
- Two standard instrument local environmental plan (LEP) clauses which introduce flood-related development controls (one mandatory, one optional).
- A SEPP amendment to replace councils existing flood planning clause with the new mandatory standard instrument clause.
- A revised local planning direction regarding flooding issued under section 9.1 of the *Environmental Planning and Assessment Act 1979* (the Act).

6.2.5. Section 10.7 (formerly Section 149) Planning Certificates

Section 10.7 Planning Certificates are issued in accordance with the EP&A Act 1979. They contain information on how a property may be used and the restrictions on development. A person may request a Section 10.7 certificate to obtain information about their own property but generally a Section 10.7 certificate will be requested when a property is to be redeveloped or sold. When land is bought or sold the Conveyancing Act 1919, requires that a Section 10.7 Planning Certificate be attached to the Contract for Sale.

Most councils' Planning Certificates are issued under Section 10.7 (2) and 10.7 (5) of the EP&A Act 1979. A separate request can be made for a Section 10.7 (2) Certificate which confirms whether complying development may be carried out under the State Environmental Planning Policy 2008 (Exempt and Complying Development). Information to be disclosed on a Section 10.7 (2) Planning Certificate is specified under the Environmental Planning and Assessment Regulation 2000 (Schedule 4) and includes the following where relevant:

- names of relevant planning controls i.e., SEPPs, LEPs, DCPs.
- declared state significant developments.
- zoning and land uses under the planning control.
- critical habitat.
- heritage information.
- land reserved for acquisition.
- coastal protection.
- mine subsidence.
- road widening and road realignment.
- Council and other public authority policies on hazard risk restrictions (including flooding).
- Section 94 contributions plans.

6.3. Local Provisions

Appropriate planning restrictions, ensuring that development is compatible with flood risk, can significantly reduce flood damages. Planning instruments are used as tools to guide new development away from high flood risk locations and ensure that new development does not increase flood risk elsewhere. They can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population. Councils use LEPs and DCPs to control development on flood prone land.

A LEP guides land use and development by zoning all land, identifying appropriate land uses that are allowed in each zone, and controlling development through other planning standards and DCPs. LEPs are made under the EP&A Act 1979 which contains mandatory provisions on what they must contain and the steps a Council must go through to prepare them. In 2006 the NSW Government initiated the Standard Instrument LEP program and produced a new standard format which all LEPs should conform to.

Sutherland Shire Council's LEP 2015 was adopted in 2015 and was prepared under the Standard Instrument LEP program, the DCP came into force in August 2017 and applies to all land in Sutherland and all types of development. DPIE's update of July 2021 (Section 6.2.4) has subsequently updated the LEP for all Councils regarding flooding.

The DCP is supplementary to the LEP and State Environmental Planning Policies (SEPPs). If there is any inconsistency between the DCP and the LEP, the LEP will prevail to the extent of the inconsistency.

A DCP specifies detailed guidelines and environmental standards for new development, which need to be considered in preparing a DA. The DCP provides a layered approach, some parts are relevant to all developments, some to specific types of development, and some to specific land.

Council's DCP is reviewed in Appendix D which covers all planning matters related to floodplain management. A significant component of the DCP is a matrix that provides the necessary flood related controls. This matrix will be reviewed as part of future work by Council (refer Section 8.4.7). Council suggested controls (Diagram 5) that should be included in an updated matrix and the elements of a matrix (Diagram 6) that should be considered in the matrix review.

Diagram 5: Suggested Controls to be Included in Updated Matrix in DCP

Controls	Change of use	Ancillary development	Major alterations & additions	Secondary dwelling	Knock down & rebuild on single lot (single building)	Knock down & rebuild on single lot (strata development)	Torrens title subdivision and redevelopment	Consolidation & redevelopment
Floor level			Yes	Yes	Yes	Yes	Yes	Yes
Building components & method	Possibly	Yes	Possibly	Yes	Yes	Yes	Yes	Yes
Structural soundness		Yes	Yes	Yes	Yes	Yes	Yes	Yes
Flood effects		Yes	Yes	Yes	Yes	Yes	Yes	Yes
Car access and parking		Yes	Yes		Yes	Yes	Yes	Yes
Emergency response	Yes		Possibly	Yes	Yes	Yes	Yes	Yes
Management & design	Yes		Yes	Yes	Yes	Yes	Yes	Yes

Diagram 6: Suggested Elements to be Considered in Updated Matrix in DCP

Element	Description
Development description	• Identify development types that are consistent with definitions in relevant SEPPs, SSLEP or SSDCP
Development purpose / use	• Identify the dominant purpose or the use of the proposed development i.e. residential, commercial / industrial, recreation / open space, community infrastructure, sensitive / critical facilities • Aids in understanding vulnerability
Consent required	• Development can be exempt, complying, permissible with consent or require no consent with reference to the Code SEPP or SSLEP? • Smaller, less complex developments up to single buildings can be exempt or complying development – anything 'greater' will require a DA
Consent applicability and implications	• What is the specific approval pathway for different types of development in the Shire and what are the implications for flood risk? • River and tributary foreshores subject to mainstream flooding are environmentally sensitive where exempt and complying development cannot be undertaken • Some types of ancillary development will suffer little flood damage and have no flood impact but other types will – this will determine the approval pathway i.e. CDC or DA
Existing building retained	• Development may involve retaining the existing building, adding to an existing building or establishing a new building in addition to the existing building • Aids in understanding the ability to reduce flood risk i.e. difficult to reduce flood risk for existing, retained buildings, but easier for new buildings
Habitable spaces	• Habitable and non-habitable in FRM pertains to the use of an internal or external space of a building and the amount of damages sustained from flooding of that space • Aids in understanding flood risk • Ancillary development is the only type of development that does not involve habitable space • Development will often involve a combination of habitable and non-habitable spaces
Intensification	• Intensification involves the increase in either people, buildings, vehicles or goods in the floodplain • Type of intensification varies with type of development • Uncontrolled intensification can increase flood risk but controlled intensification may reduce flood risk
Vulnerability	• Vulnerability is a form of flood risk pertaining to the degree of exposure to flood hazard faced by different people, buildings and facilities, and the consequences arising from that exposure • Vulnerability varies not only by development type but by who will occupy that development and the purpose of that development • Vulnerable groups include the young and the elderly; vulnerable development includes sensitive facilities e.g. childcare centres, seniors living, etc or critical facilities e.g. emergency services, critical infrastructure
Opportunity to reduce existing flood risk on property	• Applicable to redevelopment of improved lots, not development of vacant lots • Opportunity to reduce existing flood risk on the property varies with the type of development • Aim is to reduce property flood risk as far as practicable
Contribution to reducing overall flood risk	• Applicable to redevelopment of improved lots, not development of vacant lots • Opportunity to reduce existing flood risk across the floodplain varies with both the type of development and the intensity of that development in the floodplain • Considered more as part of strategic FRM rather than the DA assessment process • Aim is to use redevelopment to gradually reduce cumulative flood impact across the floodplain
Applicable controls	• The number of controls to be applied vary with the type of development, vulnerability and the degree of flood affectation and hazard

7. REVIEW OF FLOODPLAIN RISK MANAGEMENT

7.1. Overview

Although there has been no formal plan for floodplain risk management covering the Woolooware Bay catchment, the floodplain has still been managed to reduce the risk to life and property. This section initially describes those existing floodplain risk management practices regarding the three categories of management measures.

Building on the understanding of flood behaviour, flood impacts and land use planning, new mapping is then introduced that characterises the variation in risk across the floodplain. The implications for strategic land use planning, statutory planning and flood emergency response are discussed.

Principles and opportunities for managing the floodplain are introduced with reference to existing risk, continuing risk, and residual risk, which will inform the identification and assessment of specific floodplain risk management measures.

7.2. Categories of Floodplain Risk Management Measures

The 2005 NSW Government's Floodplain Development Manual (Reference 2) separates risk management measures into three broad categories.

- Flood modification measures modify the physical behaviour of a flood including depth, velocity, and redirection of flow paths. Typical measures include flood mitigation dams, retarding basins, channel modification, levees, or defined floodways and trunk drainage. Pit and pipe improvements, and even pumps may also be considered where practical.

- Response modification measures modify the response of the community to flood hazard by educating flood affected property owners about the nature of flooding so that they can make better informed decisions. Examples of such measures include provision of flood warning and emergency services, and improved community flood awareness.

- Property modification measures modify existing or new properties to reduce flood risk. For example, existing properties can be modified through house raising or flood proofing while new properties should comply with flood-related development controls.

7.3. Existing Floodplain Risk Management Practice

Until about the mid-2000s overland flow in the Woolooware Bay catchment was managed using well-established stormwater management principles and procedures such as outlined in Australian Rainfall & Runoff 1987 (Reference 3) and Council's Urban Drainage Manual 1994. The primary focus was on using the public stormwater drainage network and the application of private on-site detention (OSD) to manage flow behaviour and where possible reduce risk, usually in minor storms.

The need to address overland flow using a floodplain risk management approach was first espoused by the NSW Government in the 2001 Floodplain Development Manual and formally adopted in the 2006 version. This led Council in 2004 to commission an initial subjective assessment of overland flow across the Sutherland Shire with the intent to prioritise catchments for more detailed investigation following the floodplain risk management process outlined in the manual. The Woolooware Bay catchment was identified as a high priority.

Around 2006 Council incorporated flood-related development controls in its DCP using the risk-based planning control matrix developed previously as part of the Georges River Floodplain Risk Management Study & Plan. The results of the initial assessment of overland flow and the application of these controls, allowed flood risk for new development in overland flow catchments to be better controlled. The application of controls was further improved following the completion of the Woolooware Bay Catchment Flood Study in 2014 (Reference 1).

Flood-related development controls listed in Clause 6.3 of the Sutherland Shire LEP 2015 and Chapter 40 of the Sutherland Shire DCP 2015 are now the primary mechanism for managing flood risk in the Woolooware Bay catchment. The availability of good flood information and a detailed flood model, combined with a reasonably good industry understanding of specific flood controls, allows generally high compliance to be achieved.

Council continues to maintain and upgrade its stormwater network to address minor, localised nuisance flooding. Raising the Captain Cook Drive embankment and widening the Gannons Road rail underpass have also helped to reduce localised flooding. Otherwise, given the topography and physically constrained nature of the catchment, no major flood risk mitigation measures have been implemented.

There has been little planning for flood emergency response in overland flow catchments like Woolooware Bay. The SES local flood plan focusses primarily on mainstream flooding and traditionally has not yet had the necessary granularity to address overland flow in small catchments.

Flood emergency response is primarily reactive. Emergency services and Council will respond to flash flooding by assisting flood-affected property owners during or after a storm, closing flooded roads and removing stormwater network blockages. Response times are however constrained by the short duration of flooding and that current BoM warnings for severe thunderstorms or flash flooding are very limited in their ability to predict the specific area or time of flooding.

There is a long record of generally minor floods, however there is no evidence of major or extreme floods having occurred in living memory. The largest reasonably well documented flood was in March 1975. There is little evidence to suggest that flood affected property owners know how to respond appropriately during floods. There have also been no community flood awareness campaigns conducted in the Woolooware Bay catchment. For these reasons, community flood awareness and preparedness are considered low.

7.4. Floodplain Risk Management Mapping

Floodplain risk management mapping has been developed based on flood behaviour, flood hazard and development pattern to show the variation in flood hazard or risk across the floodplain. The mapping is designed to assist in flood emergency response planning, strategic land use planning and for general community flood awareness.

The following three types of maps have been prepared:

- Flood emergency response classification
- Flood planning constraints categories
- Flood risk precincts

7.4.1. Flood Emergency Response Classifications

Flooding can isolate properties and cut off evacuation routes. The flood emergency response classification (FERC) provides a basis for understanding the varying nature, seriousness and scale of these issues, particularly isolation, across the floodplain.

FERC mapping was prepared for the study area in accordance with *Guideline 7-2: Flood emergency response classification of the floodplain: Supporting document for Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (Reference 8). The methodology (refer to Diagram 7) was applied to the PMF design event, and the classification results presented in Appendix B (Figure B37).

Diagram 7: Flow Chart for Determining Flood Emergency Response Classifications (Reference 8)

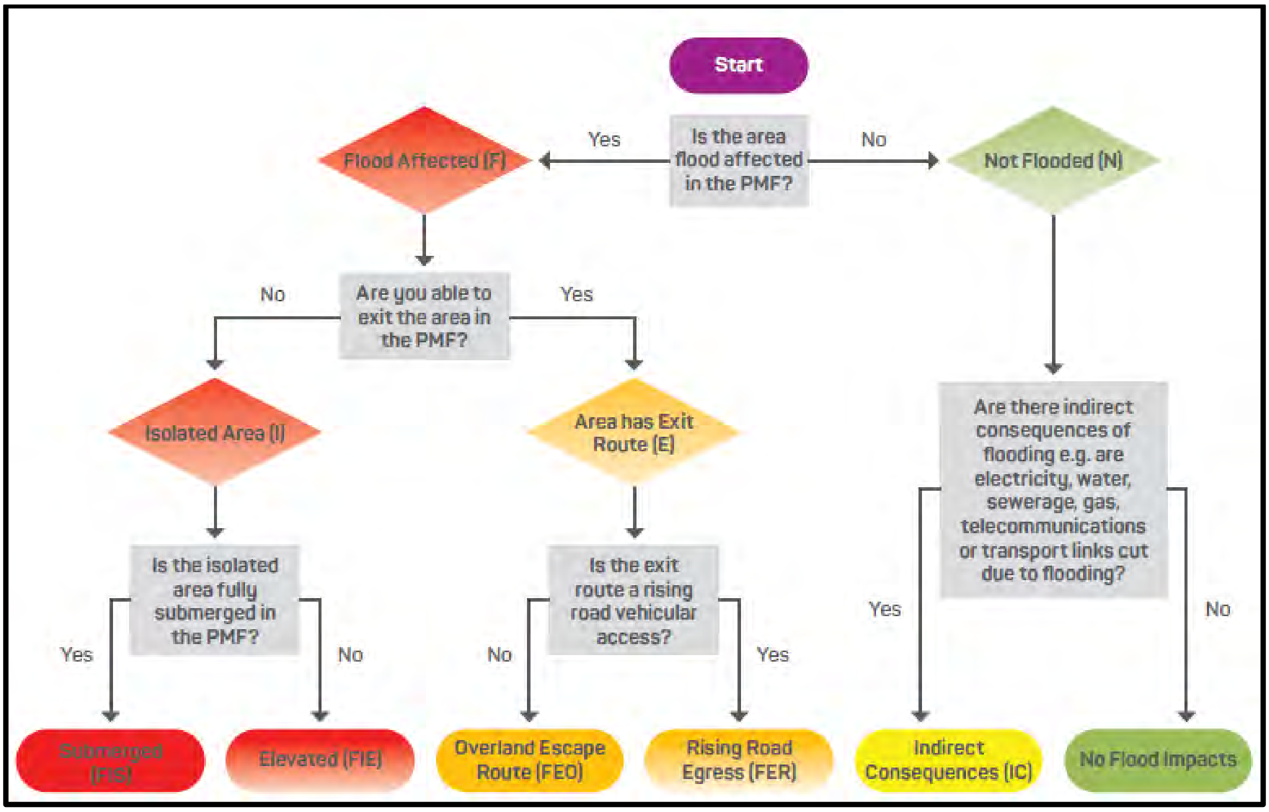


Figure B37 shows that most flood affected properties in the middle to upper catchment will have an exit route to the road. Whether this exit route rises to outside the PMF extent or drops into deeper flooding depends on the location of the property within the floodplain. The potential for becoming isolated for these properties is very low.

Properties in the lower catchment, specifically the golf courses, foreshore properties to the north of Captain Cook Drive and properties centred around Yathong Road and Fenton Avenue are submerged in the PMF.

This map is useful for understanding evacuation needs. It is important however when interpreting the maps to also consider PMF behaviour and above floor affectation. For instance, people in properties that become fully submerged in the PMF should ideally be evacuated prior to flooding, however, it may be safer for people to remain in place if the building floor level is above the PMF, is structurally resistant to floods and the duration of flooding is short.

7.4.2. Flood Planning Constraint Categories

Guideline 7-5 of the Australian Disaster Resilience Handbook Collection (Reference 9) recommends using flood planning constraint categories (FPCCs) to better inform land use planning activities. These categories condense the wealth of flood information produced in a flood study and classify the floodplain into areas with similar degrees of constraint.

FPCCs are best used for strategic planning purposes such as for local strategic planning statements, planning proposals and development of housing strategies. The categorisation is not considered as useful for statutory planning purposes, such as for the specific application of flood-related development controls.

The Australian Disaster Resilience Handbook Collection (Reference 9) recommends the use of four constraint categories. The constraints have been adapted to suit the Woolooware Bay catchment and are outlined in Table 12. The associated FPCC map is provided in Appendix B (Figure B38).

Table 12: Flood Planning Constraint Categories for the Woolooware Bay Catchment

FPCC	Constraints	Implications	Considerations
FPCC 1	Floodway and flood storage areas in the 1% AEP event H6 hazard in the 1% AEP event	Any development is likely to affect flood behaviour in the 1% AEP event and cause impacts elsewhere. Hazardous conditions considered unsafe for vehicles and people; all types of buildings considered vulnerable to structural failure.	Majority of developments and uses have adverse impacts on flood behaviour or are vulnerable. Consider limiting uses and developments to those that are compatible with flood function and hazard.
FPCC 2	Floodway in the 0.2% AEP event H5 flood hazard in the 1% AEP event H6 flood hazard in the 0.2% AEP event	People and buildings in these areas may be affected by dangerous floodwaters in rarer events. Hazardous conditions considered unsafe for vehicles and people, and all buildings vulnerable to structural damage. Hazardous conditions develop in rare events which may have implications for the development and its occupants.	Many uses and developments will be vulnerable. Consider limiting new uses to those compatible with flood function and hazard (including rarer flood flows) or consider treatments to reduce the hazard (such as filling). Consider the need for additional development control conditions to reduce the effect of flooding on the development and its occupants.
FPCC 3	Within the FPA	Hazardous conditions may exist creating issues for vehicles and people. Structural damage to buildings is unlikely.	Standard land use and development controls aimed at reducing damage and the exposure of the development to flooding are likely to be suitable. Consider additional conditions for emergency response facilities, key community infrastructure and land uses with vulnerable users.
FPCC 4	Within the PMF extent	Emergency response may rely on key community facilities such as emergency hospitals, emergency management headquarters and evacuation centres operating during an event. Recovery may rely on key utility services being able to be readily re-established after an event.	Consider the need for conditions for emergency response facilities, key community infrastructure and land uses with vulnerable users.

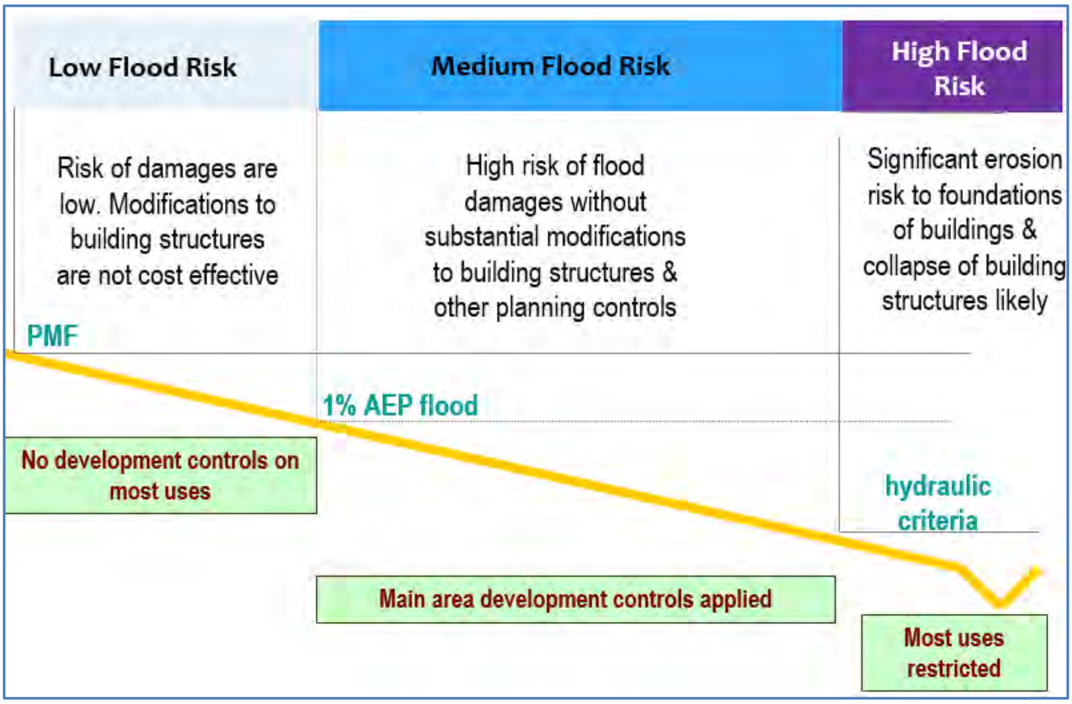
7.4.3. Flood Risk Precincts

Flood risk precinct mapping shows the variation in flood risk across the entire floodplain based on both hydraulic hazard and flood extent. Flood risk precincts are used by many councils, including Sutherland Shire Council, to drive the application of development controls and as a simple tool for publicly communicating flood risk.

Council's DCP Chapter 40 defines flood risk precincts (Diagram 8) as follows:

- Low flood risk is all land that could potentially be inundated (i.e., within the extent of the PMF) but not identified as either a high flood risk or a medium flood risk precinct. The low flood risk precinct is that area above the 1% AEP flood and most land uses would be permitted within this precinct.
- Medium flood risk is the area below the 1% AEP flood that is not subject to a high hydraulic hazard and where there are no significant evacuation difficulties. In this precinct there would still be a significant risk of flood damage or risk to life, but these damages and risks can be minimised by the application of appropriate development controls.
- High flood risk is defined as an area of land below the 1% AEP flood level that is either subject to a high hydraulic hazard or where there are significant evacuation difficulties. On land with high flood risk, there is possible danger to personal safety; evacuation by trucks would be difficult; able-bodied adults would have difficulty wading to safety; and there is a potential for significant structural damage to buildings.

Diagram 8: Flood Risk Precincts



Flood risk precinct mapping is provided in Appendix B (Figure B39). The figure shows that the high-risk precincts, similar to the 1% AEP flood hazard mapping, are relatively narrow in the middle to upper catchment traversing property and within roads, but expanding within the golf courses in the lower catchment.

In the steeper upper reaches of the catchment the low flood risk precinct does not extend far beyond the medium flood risk precinct. However, in some of the middle to lower reaches, for example, the industrial areas of Taren Point, the low-risk precinct does extend well beyond the medium risk precinct.

7.5. HotSpot Analysis

Seven hotspots have been identified as shown on Figure 7 and are detailed below.

Hotspot 1: This area is located at the base of the incline to the immediate east of Wyanbah Road, Cronulla and comprises a part open brick lined 1m wide channel. Flooding causes minimal above floor inundation or external damages but causes inconvenience and intangible damages. Resolution of this issue can only be achieved with redevelopment of all properties alongside the flow path.

Hotspot 2: Adjacent to Edinburgh Close is a 1m to 2m wide open channel within private property. Further downstream the channel is covered and exits into Woolooware golf course under Woolooware Road. In the last 10+ years redevelopment has restricted the overland flow path upstream of Woolooware Road and has effectively eliminated any viable solution to the problem.

Hotspot 3: This area commences downstream of Carabella Road, follows a drainage path at the rear of houses on Yathong Road and Murrami Avenue and exits into the tennis courts to the immediate west of Captain Cook Drive. Large parts of the floodplain are outside of private property but there is inundation of private rear yards. As redevelopment occurs the existing low-level houses will be redeveloped to comply with Council's DCP requirements. There is no viable means of eliminating overland flooding in the rear of private properties.

Hotspot 4 and 5: These are Woolooware and Cronulla golf courses respectively. Apart from damage to the grounds and indirect damages (loss of income) there is minimal risk to life and tangible damages. These golf courses are situated in these lying areas as the most suitable use of flood liable and filled land representing an excellent example of flood compatible land use. Both courses face challenges from flooding and management of creeks / small water bodies from a water quantity and quality perspective. These issues need to be addressed.

Hotspot 6: Jenola Reserve is a passive and active recreation area located east of Gannons Road and upstream of the railway line. It is also a good example of a flood compatible land use as runoff from the east enters the grounds before exiting under the rail underpass at Gannons Road. This area should be retained as a flood storage area and not filled or altered if the works will impact on flood storage or conveyance.

Hotspot 7: This area experiences overland flooding from Burraneer Road across Caringbah Road to the Kingsway. Houses on the east of Dwyer Reserve have complained of flooding issues due to the limited overland flow path. The sports field has been levelled and filled to be above the flow path. Measures could be taken to address the problem, but these would probably affect the sports field and many houses. As redevelopment occurs above floor inundation will gradually be eliminated but overland flow will still affect the amenity of the area.

7.6. Implications for Future Management

Traditional approaches to floodplain risk management were developed with a focus on larger, mainstream floodplains that are often undergoing greenfield development. These approaches need to be re-evaluated and tailored for application in smaller, fully urbanised overland flow catchments like the Woolooware Bay catchment.

Existing flood risk is usually addressed through traditional flood modification measures such as detention basins, levees, channel modification, etc. The Woolooware Bay catchment is however highly constrained with few areas of public open space that would provide opportunities for flood modification. Notwithstanding, there is a need to examine how traditional stormwater management approaches such as OSD, overland flow diversions and stormwater network upgrades could be better employed in the private domain to reduce flood risk at both a local level and floodplain wide.

Nearly all lots in the Woolooware Bay catchment contain buildings. That is, there are very few vacant, undeveloped lots. This means the dominant form of development in the Woolooware Bay catchment can be characterised as infill development or redevelopment involving a change to the existing building (e.g., alteration or addition) or a replacement of the building with another building or buildings (e.g., ‘knock down and rebuild’).

As shown in Figure 5, there are some 105 houses and 18 industrial or commercial buildings that are at risk of above-floor flooding in the 1% AEP event. This existing risk would be most effectively dealt with through redevelopment and the consequent application of flood-related development controls. Redevelopment of these flood affected properties should therefore be encouraged as a viable floodplain risk management approach.

As previously noted, current redevelopment generally achieves a high compliance with flood related development controls. Notwithstanding, there are opportunities to improve the application of controls such that the process for ensuring compliance is as clear, simple, and straightforward as possible. This ultimately will reduce the time and cost involved in the development process for the benefit of development proponents, their consultants, Council, and the wider community.

Future risk is typically associated with future development. Specifically in this instance, future risk manifests when redevelopment results in intensification, that is, when additional people or property are added to the floodplain. For example, the replacement of a single dwelling with higher density development such as a duplex or townhouses would constitute redevelopment with intensification.

The full application of flood-related development controls during redevelopment, particularly where an existing building is replaced, will provide the greatest reduction in risk to life and property, specifically tangible direct and indirect damages. However, redevelopment involving intensification where additional people are added to the floodplain, could lead to an increase in intangible flood damages such as stress and inconvenience.

Accordingly, there is a balance to be struck between promoting redevelopment to reduce existing risk to life and property and, where practicable, avoiding intensification that could lead to an unacceptable increase in intangible flood damages. Analysis of development data for the nearby Ewey Creek catchment suggests that the majority of residential redevelopment in the catchment involves retaining the existing building, suggesting that over-intensification will not be a significant issue.

Residual risk is the risk that remains once existing risk and future risk are addressed. Residual risk is addressed through voluntary behaviour modification measures such as community flood awareness programs. Such programs should be applied to residents and workers in both redeveloped properties and in existing properties with above-floor flooding, however, they should be targeted at the latter for maximum benefit.

In summary, floodplain risk management in the Woolooware Bay catchment should:

- Focus on property modification and behaviour modification measures to simultaneously address existing, future, and residual flood risk.
- Be better integrated with traditional stormwater management elements such as OSD and network upgrades.

7.7. Floodplain Risk Management Principles and Opportunities

Building on the above, a broad set of principles and opportunities for floodplain risk management have been developed to help guide the identification and assessment of individual floodplain risk management measures. Although developed in the context of the Woolooware Bay catchment, these can be applied to other floodplains across the Shire. These primarily relate to redevelopment and property modification measures given these will be the most effective in reducing flood risk.

These opportunities and principles relate to:

- development approval pathways,
- hierarchy of development control,
- vulnerability,
- flood emergency response,
- cumulative impact
- user needs.

As discussed in Section 6, development of flood-affected properties to which flood-related development controls apply (i.e., flood control lots) can either be considered and approved as complying development in accordance with the Code SEPP or through the submission of DAs and assessed in accordance with the Sutherland Shire LEP 2015 and DCP 2015. At present the pathway for approving development as complying development is generally not well understood by development proponents, consulting engineers and private certifiers.

There is an opportunity for Council to provide guidance on choosing the two approval pathways with the aim to balance Council's workload in assessing DAs with managing the risk of a sub-optimal development outcome associated with complying development.

To streamline the development assessment process while continuing to achieve compliant development, there is an opportunity for Council to provide greater guidance in the Sutherland Shire DCP 2015. This may involve expanding the current objectives and performance controls to include a set of guiding principles for redevelopment. It may also involve provide more detailed guidelines or specifications to support the application of controls in the DCP.

A key floodplain risk management principle is that the degree of development control should be commensurate with the vulnerability of the development. For example, childcare centres or nursing homes are more vulnerable to the impacts of flooding than normal residential development and should have stricter controls.

However, in applying flood-related development controls it should be acknowledged that vulnerability can be independent of the development type. For example, there may be more elderly people living in normal residential accommodation in the catchment than in dedicated seniors living or group home accommodation.

Similarly, development controls related to flood emergency management should be commensurate with the vulnerability of the development and the flood risk. For example, vulnerable development like seniors living proposed in a high flood precinct should be more tightly controlled than say normal residential development located in the low flood risk precinct. Flood emergency management controls should seek to not impose any additional burden on emergency services and be linked to or support other emergency response measures.

The DCP currently requires development proponents to consider the cumulative impact of the development. This is difficult to do given development proponents are unlikely to have the required information or framework to properly assess cumulative impacts of their specific development. Cumulative impact instead should be addressed as a strategic floodplain risk management measure and considered in the application of flood-related development controls.

Finally, there is a need to ensure that the volume of flood data generated through the floodplain risk management process is appropriately stored, analysed, displayed, and reported for easy access and use by different stakeholders and the broader community. This is again a strategic floodplain risk management measure.

8. FLOODPLAIN RISK MANAGEMENT MEASURES

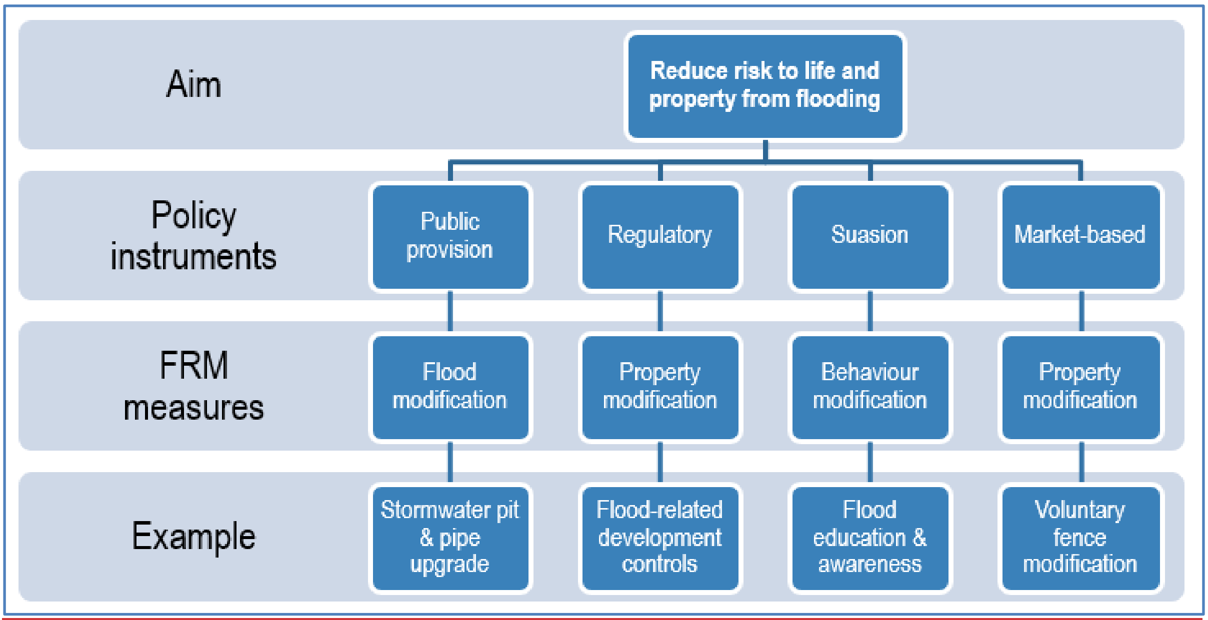
8.1. Overview

This section identifies and assesses specific floodplain risk management measures for the Woolooware Bay catchment based on the three categories of measures introduced in Section 7.2. The assessment considers economic, social, and environmental factors.

Approximate cost estimates are provided to compare options, particularly for flood modification. Costs for various property modification and response modification measures are more difficult to estimate because they usually apply to ongoing programs rather than specific projects. Estimated costs for investigations to determine the feasibility and scope of these programs are provided where appropriate.

It is important also to consider the broad policy instruments by which floodplain risk management measures can be implemented. Diagram 9 shows this relationship.

Diagram 9: Environmental Policy Instruments and Floodplain Risk Management Measures



Regulatory control and public provision are the two dominant policy instruments for floodplain risk management and most familiar to Council, development proponents and the wider community. Council the SES also have experience with suasive instruments. Market based instruments are, however, relatively new to Council but have been used by the NSW Government and other councils elsewhere to incentive property owners to reduce flood risk.

Typically, all policy instruments are needed in some combination to maximise benefit i.e., reduction in flood risk. These instruments must be designed such that they are mutually supportive.

Flood modification measures are the least effective given the lack of opportunities to undertake them in the catchment. Continued management of the stormwater drainage network using established stormwater management approaches will assist in the minor floods but cannot be considered a viable floodplain risk management measure.

Property modification involving redevelopment and the application of flood related development controls particularly where the flood affected building is replaced is the most effective in reducing damages. Voluntary flood proofing or voluntary fence modification are the next most effective measures. These are measures that are applied to existing properties and buildings that are flood affected.

Behaviour modification could be equally as effective particularly when undertaken in combination with voluntary property modification measures.

8.2. Flood Modification

8.2.1. Levees and Filling

DESCRIPTION

Levees involve the construction of raised embankments between the watercourse and flood affected areas to prevent the ingress of floodwater up to a design height. Levees usually take the form of earth embankments but can also be constructed of concrete walls or similar where there is limited space or other constraints. Small levees comprising low bunds or raised garden beds can also be built in the public domain upstream of flood affected properties to divert overland flows around the property.

Levees are more commonly used on large river systems, for example on the Hunter River at Maitland, but can also be found on small creeks in urban areas. There are a few in urban areas in the Sydney basin, one example is at Kelso Park adjacent to Henry Lawson Drive on the Georges River and in overland flow situations where they usually take the form of smaller informal bunds.

Flood gates, flap valves and pumps are often associated with levees to prevent backing up of drainage systems in the area protected by a levee and/or to remove ponding of local water behind the levee.

DISCUSSION

Once constructed, levee systems generally have a low maintenance cost although the levee system needs to be inspected on a regular basis for erosion or failure. Although a levee can keep out flood waters, flooding can occur within the levee due to local runoff being unable to drain. In addition, as the levee causes a displacement of water from one area of the floodplain to another, they should be carefully designed using hydraulic modelling techniques to ensure the levee does not increase flood risk to an adjacent area.

The design height of the levee is the event for which it prevents flooding and usually also includes a freeboard above the design height to allow for settlement of the structure overtime or variations in flood levels due to the behaviour of the flood event, wave action from passing vehicles or watercraft and effects of wind.

Table 13 provides a summary of the key issues to be considered with levee construction.

Table 13: Key Features of Levee Systems

ISSUE	COMMENT
ADVANTAGES:	
Can be an environmentally sensitive measure.	A well-designed vegetated earthen embankment set back far enough from the riverbank to retain floodplain access, and that does not interrupt local drainage, can have minimal environmental impact providing that the natural wetland hydrology is not affected. However, in many urban locations it is hard to meet all these criteria.
Protects many buildings.	Along a creek or overland flow path in an urban area this is generally not possible.
Can provide a high level of protection.	This is possible in overland flow areas where there is only a relatively small height difference between the design events.
Low maintenance cost.	A levee system needs to be inspected annually for erosion or failure. In addition, there is ongoing weekly or monthly maintenance (grass cutting, vegetation trimming). The annual cost of inspections for erosion or failure (of say flood gates) will generally be small (say less than $10,000 per annum per levee). However, this amount can vary considerably depending upon the complexity and size of the structure.
DISADVANTAGES:	
Visually obtrusive to residents.	Residents enjoy overlooking a creek system or an open grassed area because of the visual attraction and a (say) 1.0 m high embankment will significantly affect their vista. Anything which reduces the vista is unlikely to be accepted by most residents. A freeboard of usually 0.5 m to 1 m should be added to the design flood level of the levee (level of protection afforded by the levee) to account for wave action, slumping of the levee or other local effects.
High cost	The cost to import fill, compact and construct an earthen levee is dependent on the availability of good quality fill and the associated transport costs, these will vary depending upon the locality. However, generally it is the land take and associated costs (possible services re-location and access) which add considerably to the cost. This is particularly an issue in the Woolooware Bay catchment due to the high land values.
Low benefit cost ratio	Whilst the levee system may protect several buildings from being inundated in a (say) 1% AEP event it is likely to have a low benefit cost ratio unless the levee can include buildings inundated (and so being able to be protected) in the more frequent floods (less than a 10% AEP event). Typically, these frequently inundated buildings are not concentrated in an area that can readily be protected by a levee.
Local runoff from within the "protected area" or upstream may cause inundation.	The ponding of local runoff from within the "protected area" may produce levels similar to that from the creek itself. In some places local runoff already causes problems in several areas. Constructing a levee will compound this problem. It can be addressed by the installation of pumps or flap valves on pipes, but these add to the cost and the risk of failure.
May create a false sense of security.	Unless the levee system is constructed to above the PMF level it will be overtopped. When this occurs, the damages are likely to be higher as the population will be much less flood aware (as happened in New Orleans, USA in August 2005 and in Lismore, NSW).
Relaxation of flood related planning controls.	Most residents consider that following construction of a levee the existing flood related planning controls (minimum floor level, structural integrity certificate) should be relaxed. However, many experts consider that this should not be the case unless the levee is built to the PMF level and the risk of failure is nil. The general opinion is that a levee should reduce flood damages to existing development but should not be used as a means of protecting new buildings through a reduction in existing standards. When residents become aware of this philosophy many change their support for a levee.
Restricted access to the creek system.	Access to the creek system for recreational activities requiring easy access will be restricted. This can be addressed by (expensive) re-design of entry points. This is unlikely to be an issue

ISSUE	COMMENT
	in this catchment.
Increase in flood levels elsewhere.	Levees by their very nature prevent inundation of part of the floodplain. The floodwaters that previously entered the protected area must now travel elsewhere and in so doing increase flows and flood levels elsewhere. The increase in level depends upon whether the area to be leveed was a flood storage area with no or little cross flow or the area was an area of active flow, termed a floodway. This can be a significant issue in overland flow urban areas due to the density of development.
Tying the levee into high ground.	Unless the levee is a ring levee it must tie into high ground. This is likely to be a significant issue as it may require raising roads or significantly extending the levee alignment.

Large levees are not practical in the Woolooware Bay catchment for several reasons. Firstly, open channels in the lower catchment within the two golf courses and downstream already convey major floods and there are no adjacent houses that would benefit from additional flood protection.

Secondly, channels in the middle catchment to the south of Captain Cook Drive do not convey a large proportion of the flood flows and any levee would likely be outflanked by overland flow, for example the Yathong Road / Murrami Avenue channel.

Thirdly it is difficult to construct levees in private property and there are no available suitable public lands.

Dwyer Reserve is the only area of open space in the catchment where a small levee could be considered. A low wall installed at the south-west corner and western boundary of No 222 Kingsway, together with some regrading of surrounding ground levels, could be used to increase the diversion of overland flows northwards along the public path towards the Kingsway (subject to assessing the flood affects for No. 224 the Kingsway). This could benefit properties located around the Kingsway / Gannons Road intersection, particularly dwellings at No. 220 and No. 222 Kingsway and No. 69 Gannons Road which are at risk of above floor flooding. For many reasons as provided in Table 13 this option was not pursued.

RECOMMENDATIONS

In an urban environment it is difficult to construct a levee that provides protection and at the same time does not affect access and/or views or re-distributes floodwaters onto adjoining properties. A levee at Dwyer Reserve was not considered viable and no other suitable sites were identified in the catchment.

8.2.2. Temporary Flood Barriers

DESCRIPTION

Temporary flood barriers include demountable defences, wall systems and sandbagging for deployment prior to the onset of flooding. There are examples in Sydney where shops install a temporary steel barrier at the door if heavy rain is forecast.

DISCUSSION

Demountable defences can be used to protect large areas and are often used to assist in current mitigation measures rather than as sole protection measures. For example, they are best used to fill gaps in levees or to raise them as the risk of levee overtopping develops. The effectiveness of these measures relies on sufficient warning time and the ability of a workforce to install. They are more likely to be used for mainstream flooding from rivers which have sufficient warning time and are not a suitable technique for smaller catchments with shorter response times.

Temporary flood barriers in urban environments often comprising sandbag walls or proprietary systems, can be deployed in the public domain, usually by emergency services. Sandbags or vertical boards can also be deployed by property owners to prevent ingress of floodwaters into buildings via doors and vents. The effectiveness of temporary flood barriers deployed in the public domain in the Woolooware Bay catchment is limited given the short flood warning times, the lack of available space to deploy, wide overland flow paths and possibly that a large diversion could adversely impact other properties. Temporary flood barriers in the private domain are a more feasible option. Their success depends on having sufficient warning time, the barrier ready to hand and someone at the property to deploy it. For these reasons, temporary flood barriers should be considered a flood emergency response measure that can be promoted as part of a community flood awareness program.

An important issue with temporary flood barriers is that they will only be used very infrequently (possibly once every several years). Thus, without maintenance or testing of the barrier there is the possibility that the barrier will not work, or the operator may not know how it works. Regular maintenance and testing of the barrier are therefore essential.

RECOMMENDATIONS

In the Woolooware Bay catchment, demountable defences are generally not suitable to reduce flood risk and inundation to residential buildings, due to the lack of suitable locations for their placement and insufficient available warning time. However, for non-residential buildings or suitable residential buildings they may offer a means of protection and if appropriate should be considered further by these building owners. This measure would generally not be funded through the Statewide flood mitigation program.

8.2.3. Channel Construction

DESCRIPTION

Channels can be an effective way to transfer and confine flow in a flooding situation and can aid in reducing peak flood levels, extents and duration.

DISCUSSION

In a relatively densely inhabited urban area, there is generally little scope to undertake this measure as it will have been considered in the past and where viable, already undertaken. This measure may require additional land take, will generally involve significant costs, and may have adverse environmental impacts.

Construction of new open channels would only be feasible in the lower catchment north of Captain Cook Drive, particularly on and around Solander playing field, where there is sufficient open space in the public and private domain. However, there are few adjacent properties or buildings that would benefit from the additional conveyance capacity provided by the works.

RECOMMENDATIONS

No suitable sites were found which would provide significant reduction in flood levels without significant adverse social, economic or environmental impacts.

8.2.4. Channel Modification

DESCRIPTION

Channel modifications are undertaken to improve the conveyance and/or capacity of a creek or drainage system. This includes a range of measures from straightening, concrete lining, removal / augmentation of structures, dredging and vegetation clearing. Channel modifications may reduce flood levels at the location of the works but need careful planning to ensure that the flood risk is not exacerbated downstream.

DISCUSSION

The open channel areas within the study area (i.e., withing the two golf courses) are relatively efficient carriers of flood waters and little benefit can be obtained through modifications to these channels. Concrete lining or straightening cannot be justified in an urban area for social and environmental reasons. In many urban areas vegetation clearing is often suggested by the local community to increase the channel conveyance. However, in the Woolooware Bay catchment vegetation clearing does not appear to be of significant concern. The exception is on the two golf courses and this issue is discussed further in Section 9.3.

Channel modification involves increasing channel dimensions, reducing hydraulic roughness, or straightening a channel to increase channel slope, to increase conveyance capacity. Existing channels in the catchment are either the remnants of creeks or have been constructed during catchment clearing, subdivision and urban development. In both instances, the channels are already heavily modified. There is little available space to widen or straighten channels. Vegetated channels in the two golf courses and at Yathong Road / Murrami Avenue could be concreted to reduce hydraulic roughness however this would have large environmental impacts with very little reduction in flood levels or flood risk.

The mangrove-lined channel adjacent to the west of the football ground could be dredged to provide additional capacity. This could provide some benefit in reducing the duration of ponding on Captain Cook Drive, most noticeably for floods occurring at low tide. Wider reductions in flood levels are minimal given the channel is already conveying large flood flows. The environmental impacts of dredging would be significant particularly given the channel's connection to the Towra Point Aquatic Reserve.

RECOMMENDATIONS

Channel modification measures were considered to provide little benefit to developed land and would likely lead to increased flood affectation downstream. Additionally, environmental impacts are likely to be significant. As such, channel modification was not considered further and accordingly the associated economic, social and environmental impacts of implementation have not been investigated.

It should also be noted that Sutherland Shire Council with the help of Bushcare volunteers and contractors already undertakes weed control, bush regeneration and appropriate vegetation clearing along all of Council's creek systems.

8.2.5. Major Structure Modification

DESCRIPTION

Hydraulic controls such as bridges or major culverts on significant waterways can affect upstream flood levels due to backwatering effects. By increasing hydraulic conveyance, flood levels upstream of a structure can be decreased. Generally, the most effective way of increasing hydraulic conveyance is by increasing the cross-sectional area (normal to the flow direction). This is often done by increasing the size of a culvert, widening a bridge, or raising the deck level.

DISCUSSION

Increasing bridge or culvert capacity under road crossings will reduce food levels upstream. However, as flood levels are reduced upstream there is less temporary floodplain storage upstream and thus a slight increase in peak flow downstream. It is this increase in peak flow downstream as well as the significant cost that prevents the use of this measure in the catchment.

One possible location mentioned by several parties is the twin culvert crossing of Captain Cook Drive from Woolooware golf course into the mangrove lined open channel on the west side of the football ground. This issue is discussed in detail in Section 9.2. Other crossings of Captain Cook Drive were considered but were not considered viable.

RECOMMENDATIONS

All road crossings were investigated with a view to implementing this measure. However, no locations were found that could be justified considering the high cost, limited reduction in peak flood level upstream and likely adverse impact downstream.

As such, major structure modification was not considered further and accordingly the associated economic, social and environmental impacts of implementation have not been investigated.

8.2.6. Creek and Drainage Maintenance

DESCRIPTION

Maintenance of the drainage network is important to ensure it is operating with maximum efficiency and to reduce the risk of blockage or failure. Maintenance involves regularly removing unwanted vegetation and other debris from the drainage network, particularly at culverts and small bridges.

DISCUSSION

A common issue with all residents in flood liable areas is the perceived lack of maintenance within the creek or piped drainage systems by Council. This perception arises as residents see the build-up of debris either before during or after the event and think that this is a major contributor to flooding.

The following provides a summary of Council's record of creek and drainage maintenance in the catchment:

- blockage of street inlet pits as well as tree root entry has occurred at several places.
- there have been no reports of significant blockage at major waterway structures.
- blockage of the creek and culvert system in Woolooware golf course has occurred in the past and Council has undertaken works to remove vegetation and unblock culverts (refer Section 9.3 for further details).
- flooding on Captain Cook Drive has caused "wheelie bins" and similar "manmade debris" to collect at the kerb inlet pits, however these have had little influence on flood levels and are quickly cleared by Council.
- the build-up of debris in culverts exiting to Woolooware Bay and in the mangrove lined channel on the west side of the football stadium has occurred and this is addressed further in Section 9.2.

Whilst debris build-up does contribute to increased flood levels the issue is more complex than may be first assumed for the following reasons:

- Council already has a rigorous debris removal program for the pit and pipe network. The program includes four sites within the catchment that are inspected on a 3 monthly basis and two on a 12 monthly basis. However, an inspection may be undertaken on a more frequent basis if there is a need.
- Council does undertake creek clearing if advised of major debris build up (fallen trees or similar).
- It is generally only during a storm event that there is a major release of debris into the drainage system due to fallen trees, wheelie bins swept into the creek, fences fallen over or water and wind sweeping debris from yards or other sources. Maintenance prior to the event does little to reduce these debris sources.
- Blockage of small culverts has little impact in large events as the percentage of flow in these structures is very small and thus has only a small impact on peak flood levels.

Structure blockage can be improved with the introduction of maintenance protocols or policies to ensure that drainage assets are effectively managed and regularly maintained. These policies aim to ensure that assets will perform when they are needed. Alternatively, the implementation of trash racks or bollards upstream of structures could be considered by Council to keep structures free of debris. The cost of trash racks or bollards varies greatly depending upon the nature of the structure. An indicative cost is $5,000 to $20,000 per item.

Council maintains open channels across the catchment on an as-needs basis. Maintenance involves the removal of excess sediment or debris. GPTs have also been installed to reduce the amount of sediment and debris reaching the channels. Maintenance of open channels in the middle catchment will assist in reducing flooding only in very minor events given that these channels have only a limited conveyance capacity.

Council has received few reports of blockages of channels and culverts beneath Captain Cook Drive that have exacerbated flooding. Notwithstanding, a blockage analysis of culverts under Captain Cook Drive should be undertaken in accordance with the procedures outlined in ARR

2019 to determine if debris control structures would be of benefit in reducing the risk of blockage and consequent increases in flood levels.

The construction of sedimentation basins on the channels upstream of Captain Cook Drive, were also canvassed. Such basins can capture sediment before entering downstream channels and are easier to maintain than the channels. Basins would be costly to construct and, like channel modification measures, are not likely to assist in reducing flood levels or flood damages.

Council maintains its stormwater pit and pipe network on both a proactive and as-needs basis. There are several locations in the catchment where stormwater pits are cleaned every three to six months. While proactive and as-needs cleaning will reduce the incidence of nuisance flooding (i.e., flooding in very minor storms), network capacity modelling has shown that the stormwater pit and pipe network conveys only a small proportion of major flood flows and surcharges in events as low as the 50% AEP. Overland flood behaviour in large events (causing above floor inundation) such as the 1% AEP are thus relatively insensitive to pit blockage factors. Increasing proactive cleaning of the network will therefore have very little benefit in large design events.

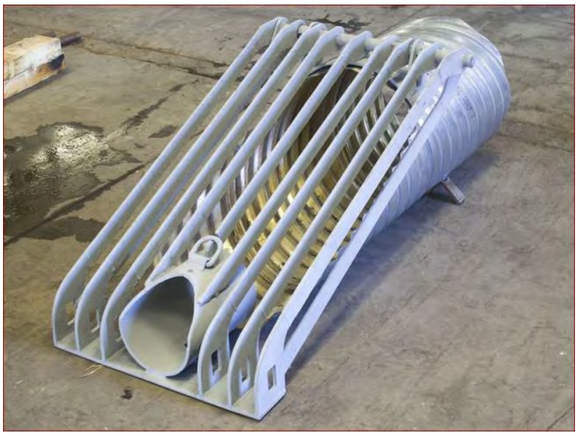
The management of low-lying tidal waterway infrastructure, sea level climate change, rehabilitation of sustainable watercourses and addressing sediment transport from upstream lands is complex. Council has an upcoming $1+ million waterway management program which will review these issues to ensure best environmental practice in both water quality and quantity.

RECOMMENDATIONS

Council already has an appropriate creek and drainage maintenance program and has no records of debris build up in past floods which have significantly increased flood levels. However, it is important that this measure is reviewed by Council to ensure that it is working efficiently and effectively as possible. The following guidelines are proposed to minimise the risk of blockage.

- Ensure that as far as possible significant amounts of debris (natural and manmade) are regularly removed from the creek system and particularly at culvert and bridge crossings.
- Ensure man made debris will not enter the creek system. This may include inspecting the creek system to ensure potential debris providing locations are identified and controlled.
- Following each flood undertake a survey of the creek system and contact residents to establish where significant blockages have occurred.
- Where debris continually accumulates then debris control structures could be installed (Photo 7). However, these are never 100% effective and, in some cases, may accentuate the problem by acting as a debris collector themselves.

Photo 7: Example of Blockage Prevention device



Residents are reminded to take photographs and to advise Council of any debris build-up in the pit and pipe or creek systems. This will ensure that reported problem areas can be addressed.

Some Councils have introduced silt and vegetation management plans to address this issue. However, it is acknowledged that these schemes are costly for Councils to operate and must be continued forever to be effective.

8.2.7. Retarding Basins and OSD

DESCRIPTION

Retarding basins and OSD work by storing and controlled release of runoff after the event peak. These measures are appropriate for use in controlling flooding by mitigating the effects of increased runoff caused by urban development. They can be either installed as part of a new development to prevent increases in runoff rates or retrofitted into existing catchment drainage systems to alleviate existing flood problems. Retarding basins are widely used in greenfield developments but are difficult to retrofit in existing long standing urbanised catchments.

All areas of temporary floodplain storage in the catchment will act as a form of retarding basin and so attenuate the peak flow downstream. However, it should be noted that apart from OSD basins there are no designed retarding basins in the catchment. Thus, the ponds in Woolooware and Cronulla golf courses were not designed to mitigate peak flows downstream and nor were the baseball playing fields on the eastern intersection of Captain Cook Drive and Gannons Road. Even though they obviously do act as retarding basins there is little value in designing these areas as retarding basins as there are no significant assets downstream to protect.

Development increases the peak rate of flow by changing pervious into impervious surfaces. OSD is implemented by all councils in Sydney to ensure that the peak flows emanating from a "to be developed" catchment will not be increased above that under the "natural" catchment conditions. However, OSD is generally not viable as a means of reducing flood levels along the main overland flow paths as the storages are too small and there are too few of them. As a means of mitigating the adverse effect of urbanisation they are appropriate, and this is discussed below.

DISCUSSION

Retarding basins can significantly reduce peak flows and are typically cost effective and easy to implement provided there is a suitable location available. Hydraulic structures, such as low flow culverts at the bottom of a basin, can be used to restrict the discharge rates from the site to a variable rate, dependent on rainfall volumes and the hydraulic head in the retarding basin.

Possible sites in the two golf courses, Fenton Avenue Reserve, Dwyer Reserve and Jenola playing fields have all been considered as possible sites. As noted previously there is no suitable site to create a large flood mitigation basin within the catchment. Whilst retarding basins appear to be a simple and effective means of controlling runoff and water quality in urban catchments there are several potential issues that need to be resolved. Importantly it should be noted that basins only reduce flood levels downstream not upstream. Unless considerable excavation is undertaken the flood levels at the site of the basin and possibly upstream will increase. These and other issues are summarised in Table 14 below.

Table 14: Considerations for Retarding Basins

ISSUE	COMMENT
Size and Location:	To be effective at reducing peak flows and benefiting water quality the basin area must cover a reasonably high percentage of the upstream catchment. The larger the basin, the more effective it will be. The outlet controls are also important in the design of the basin and generally comprise a low flow culvert and a weir which overtops in a large event. It is difficult therefore to find a location which can accommodate a basin and is not used for some other purpose.
Cost:	Whilst construction costs of the basin and wall in an urban environment will be high, additional costs are associated with any alterations to services (gas, electricity, telephone, water, sewerage, roads, etc.) that are within or near the proposed basin. There will also be some ongoing maintenance cost. Some sites in urban areas, which at first glance may appear suitable, are unviable due to the deposition of inappropriate fill material in the past (ex-rubbish site, buried asbestos or other forms of waste).
Benefit:	Whilst any basin will provide some peak flow reduction and water quality benefit this must be balanced against the cost, and whether there are more cost-effective methods. For example, it is generally acknowledged that public education and awareness and point source reduction provides the greatest benefit from a water quality perspective. The benefit for peak flow reduction is subject to the size of the basin and the outlet works. These are not easily defined at a concept stage, as detailed survey and design is required. Small basins generally provide the greatest peak flow reduction in small more frequent events, when the basin volume is a high percentage of the total flood volume. However, in these events there is often only minor above floor damage or minor hazard to mitigate. In large events, basins (unless very big) are largely ineffectual from both a water quality and peak flow reduction perspective. Also, for multi-peaked rainfall events the basin may provide some benefit in the initial peak but very little when the second or third peak arrives. The use of a basin for dual purposes (water quality and peak flow reduction) generally means that a compromise of the benefits for each purpose must be reached. This is because the water quality purpose is best achieved by containing all the frequent inflows. For flood mitigation purposes, these flows are generally not contained to allow the volume in the basin to be "empty" at the time of the peak inflow.
Competing Land Use and Availability of Land:	In a relatively dense urban catchment, where areas of open space are very valuable, the loss of previously useable land is significant. Basins can have multi-uses, such as being used as sports fields when dry, but this can be difficult to achieve.
Environmental Impact:	In urban areas there is likely to be a high environmental impact with removal of vegetation and construction of an embankment wall and the lack of a potential basin site obviously restricts the use of this mitigation measure. The most preferred sites are within golf courses or any sports ground where many of the above issues can be negated.

ISSUE	COMMENT
	Examples in Sydney are in Fox Hills (Prospect) and Muirfield (North Rocks) golf courses or in a soccer field at Bateau Bay. As the two golf courses in the catchment have no significant development downstream there is no benefit in re-designing these to act as retarding basins.
Safety:	This is one of the most important factors to be considered when constructing a basin within a downstream urban area. Construction of a basin will change an open space area with a low hazard potential during rainfall events to an area with a greater hazard potential. Apart from the risk of wall failure and consequently a sudden rush of floodwaters, there is the risk that people may drown or be swept into the basin. This can be negated by using fencing, but this then precludes the use of the basin for other purposes. Generally, basins deeper than say 1.2 m are unacceptable as a person cannot wade out of them. Some basins can be designed to have shallow and gradual depths closer to the edges. However, this means less potential storage volume over the same land area. The benefit of a reduction in hazard downstream must be balanced with the potential increase in hazard at the basin site. Constructing a basin may place a significant potential liability on the construction authority should it cause harm to persons in flood (or even non-flood) times. Signs can be placed advising of the hazard, however in a legal environment it is difficult to argue that this removes the construction authority's responsibilities. Also, children, older residents and non-English speaking background residents may not understand the signs.

Existing detention storage at Woolooware golf course could be increased by excavating land immediately to the south of Captain Cook Drive, to reduce the depth and duration of inundation over Captain Cook Drive. This measure would be extremely costly and have significant social and environmental impacts. A benefit cost ratio would be difficult to calculate given the uncertainty in benefits of a reduced time of closure of Captain Cook Drive, however the ratio is expected to be very low.

Fenton Avenue Reserve could be formed as a detention basin by reducing ground levels, to reduce downstream flooding of the prior Toyota site. Like Woolooware golf course, this would have significant financial, social and environmental impacts with little expected benefit. Flood risk on the prior Toyota site is most effectively addressed through the planned redevelopment of the site and the application of flood-related development controls.

A detention basin could be constructed at Dwyer Reserve by lowering the level of the field and constructing an embankment at the north-east corner of the field. Financial and social costs of this option would be high, and overall benefit costs are expected to be low. Flood risk of properties at the Kingsway / Gannons Road intersection is considered best addressed through property modification and flood emergency response measures.

Dwyer Reserve and the railway embankment already detain floodwaters. Ground levels could be reduced to increase the detention storage and so reduce downstream flood levels particularly at No. 97-103 and No. 105 Denman Avenue. However, these properties are some 200m downstream and thus the reduction in peak levels would not justify the expected financial and social costs.

Construction of retarding basins is not considered a cost-effective measure to negate flooding problems in the Woolooware Bay catchment. However, all basins (however small) will provide some flow mitigation and water quality benefit. The benefit that can be achieved must be balanced against the loss of use of the land and concerns about liability if construction of a basin increases the flood hazard in the area.

OSD was first adopted by local authorities in the mid 1980's and the Upper Parramatta River Trust was a key contributor to its development. At the time there was significant discussion at conferences about the need for OSD and the technical details. All Sydney councils now implement some form of OSD otherwise the downstream floodplain users would receive increased peak flows and thus increased peak flood levels when new development occurs.

OSD is governed by applying a site storage requirement (SSR) and a permissible site discharge (PSD) to each property. The SSR and PSD are determined from a catchment-based study and are unique to a specific sized catchment and the extent/location of development. For example, in the upper part of an existing developed catchment OSD will ensure that the piped drainage system and properties immediately downstream do not receive increased peak flows from the proposed development. However, in the lower part of the catchment, where the drainage system feeds into an estuary or large river system, the increased rate of runoff from a new development may be beneficial as this means the runoff has disappeared before the upstream peak arrives. For this reason, many Councils have a line below which no OSD is required.

The incorporation of OSD on new developments will generally not provide any benefit in reducing existing flood levels in the study area but is supported as a means of mitigating the increases in peak flows which would result in increased flood levels. OSD would only be applied where there is a drainage system downstream that would be affected by the increase in flow.

The technical basis for determination of the SSR and PSD were based on best practice at the time using ARR 1987 rainfall data and employed various hydrologic and hydraulic modelling approaches. The method of determining the SSR and PSD for a catchment varies between consultants and Councils. Subsequently there have been significant improvements in the modelling approaches, notably hydraulic modelling, as well as the introduction of ARR 2019. There has been no significant technical review of OSD policies in the last 10 years. Most, if not all, council OSD policies in Sydney therefore should be reviewed considering these advancements.

Since the introduction in the mid 1980's some floodplain managers have questioned the appropriateness of OSD throughout a catchment. For example, if OSD is not applied in downstream areas this means that there will likely be increases in peak flow along the downstream minor drainage paths. Another issue is whether oversized rainwater tanks can be employed as part of an OSD system. Some Councils also do not apply OSD if the land is inundated in the 1% AEP event, but this needs to be clarified in Council's policy. In Sutherland Shire positive covenants are no longer placed on OSD structures and thus maintenance is likely to be poor as no inspections will be undertaken. Possibly approved and required OSD structures will be removed or altered, thus their mitigation benefit will be negated or significantly reduced.

Sutherland Council's OSD guideline is assumed to be based on a Sydney Coastal Councils Group 1997 document that is not specific to Sutherland Shire. The guideline was also not linked to any floodplain management strategy for the catchment.

The review of Council's OSD policy is a priority because it is essentially the only means by which flood behaviour can be modified. However, there is little evidence that Council's OSD policy is set-up to ensure that there is no increase in flood risk. OSD is a site stormwater management measure, but it has not been linked to floodplain risk management in the Shire. Opportunities should be pursued for not just maintaining existing flood risk but also reducing flood risk over the long-term using on-site retention as a part of a yield minimisation strategy. Reductions in flood risk are proportional to the rate of redevelopment in the catchment.

RECOMMENDATIONS

Retarding basins were not found to be suitable for flood mitigation in the study area.

The application of OSD should be continued and linked to stormwater flooding. However, OSD is more complex than originally envisaged and updating the OSD philosophy and the SSR and PSD requirements for this and other catchments in the LGA must be undertaken using current best practice modelling. Woolooware Bay catchment could be used for testing of the updated OSD policy. A feasibility investigation to assess the impacts of OSD on flooding is $100,000.

8.2.8. Pipe Upgrades

DESCRIPTION

Most Council owned pit and pipe networks in Sydney have generally less than 20% AEP capacity and in many areas much less. Upgrading can potentially provide a significant reduction in overland flow in small events (up to the 20% AEP), however in large events, such as the 1% AEP, there will only be a minor benefit. Pipe upgrades are generally considered by residents to be a relatively simple solution to flooding problems but, it is a lot more complex and difficult.

DISCUSSION

Since approximately the 1980's, sub-divisions in western Sydney have generally had their pit and pipe networks designed for a 10% AEP or greater capacity. Upgrading an existing network in well-established urban areas has many issues, including the following.

- High installation cost of upgrading within roads due to restrictions from other services (gas, water, sewer, telecommunications) and likely road closure issues.
- Within private property it can be near impossible to upgrade if the alignment is restricted by fences, swimming pools, sheds, brick walls or other impediments. If the pipe is within an easement, it should be easier to obtain access but may still be difficult if the landowner is not accepting of the upgrade.
- Within roads the presence of services or other may restrictions can limit the size of the upgrade pipe meaning that the design upgrade size cannot be achieved.
- The benefits of a pipe upgrade can only be realised once the upgrade is completed to the downstream outlet, i.e., Woolooware Bay or a golf course. Thus, it may take years to achieve, and other mitigation measures or re-development of the affected properties may have addressed the issue in the intervening years.

TUFLOW modelling and inspection has been undertaken to assess whether there are any parts of the network that are of low capacity and could be upgraded relatively easily. None were found.

A cost benefit analysis of network upgrades is impossible to accurately determine as the benefit is largely intangible, such as reduced inconvenience or increased safety. Also, all existing problem areas have already been addressed by Council in response to previous floods.

Pit and pipe survey work incorporating pipes greater than 750mm in diameter is eligible for State Government grant funding. The augmentation of a stormwater system that results in a demonstrated reduction in overland flooding and other associated risks and is also recommended in an adopted FRMS&P is eligible for grant funding. This can include a pipe network smaller than 750mm in diameter.

RECOMMENDATIONS

Pipe upgrades will reduce flooding in small events and should be undertaken where possible. However, a timetabled program of upgrades cannot be justified due to the many inherent issues.

Council's approach to pit and pipe network upgrades should be:

- Undertake upgrades when the opportunities arise, for example in conjunction with required road or other works. The size of the pipe upgrade should be determined at the time considering the available information.
- If pipe realignment is undertaken in private or public property, the developer (private or otherwise) should upgrade the pipe to a minimum 10% AEP capacity and preferably the 5% AEP capacity.

8.2.9. Assessment of Sedimentation and Blockage in Waterways and Pipes Exiting to Woolooware Bay

DESCRIPTION

Prior to European settlement the drainage lines exiting to Woolooware Bay would have been ill defined pathways through mangroves. Subsequent filling of large parts of mangroves and ultimately concentration of runoff into relatively defined flow paths (Table 15) has introduced several issues related to drainage, flooding and water quality.

Table 15: Major Flow Paths Exiting to Woolooware Bay

Location (refer Figure 1)	Description
Mangrove lined channel exiting from Woolooware golf course through twin box culverts under Captain Cook Drive and into a 180m long mangrove lined open channel.	Whilst this is a manmade channel it is in a semi natural state and fringed by mangroves. It is understood that it has never been maintained by Council (i.e., works undertaken to remove sediment or vegetation). A footbridge and service pipes cross the channel. The channel width has likely been altered at various times due to developments on either side.
Car park on eastern side of Solander Fields	Floodwaters travel by overland flow down the sealed road which exit into the mangroves. There is also a small diameter pipe beneath the road which exits through a headwall into the mangroves.
Several small culverts	These take runoff from Cronulla golf course and from the former Toyota site and to the west into Woolooware Bay.

DISCUSSION

Of concern to residents and Council is the possible reduction in the capacity of these defined flow paths due to sedimentation (Photo 8) and or debris build up. Sedimentation is a common problem that affects all runoff exit points into Woolooware Bay or other substantial waterway.

Photo 8: Sediment build up in a culvert

These can be mitigated by maintenance undertaken by Council. Maintenance is expensive, requires an on-going commitment from Council and is not always regarded as an ecologically sustainable approach. Particularly if undertaken in an open unlined channel, such as the open mangrove lined channel on the western side of the football field. This issue has been addressed through assessment of the following scenarios for the 50%, 20% and 1% AEP catchment events and a 50% AEP event which only falls in the area downstream from approximately 100m upstream of Captain Cook Drive:

- 50% blockage of all culverts entering the Bay and filling in of the bed of the open channel exiting from Woolooware golf course to 0.5m AHD.
- 100% blockage of all culverts entering the Bay and filling in of the bed of the open channel exiting from Woolooware golf course to 1m AHD.

The results have been compared to the existing profile in the open channel and all culverts were assumed to be 100% open. This is a different assumption to that adopted in the design flood analysis shown in Appendix B as these results included blockage.

The results shown on Figure E1 to E8 indicate the following.

- In a 50% AEP local event the increases in peak levels upstream of Captain Cook Drive are largely confined to the two golf courses. There are minimal impacts on Captain Cook Drive.
- In the 50%, 20% and 1% AEP catchment events the impacts in the 50% blockage scenario are largely confined to downstream of Captain Cook Drive and Woolooware golf course. There are minimal impacts on Captain Cook Drive.
- In the 50%, 20% and 1% AEP catchment events with 100% blockage the impacts are much more extensive, affecting properties in Taren Point adjacent to Woolooware Bay and on the west side of Captain Cook Drive opposite Endeavour Road. There are also significant increases in Cronulla golf course as the culverts under Captain Cook Drive are the only exit to Woolooware Bay. There are impacts on Captain Cook Drive east of

Gannons Road of up to 0.2m in the 1%AEP event.

It should be noted that there are infinite combinations of rainfall durations, patterns, magnitude as well as blockage scenarios and associated tidal level and results in these events may differ from those reported in Appendix E.

OUTCOMES

50% blockage of the culverts and filling the channel to 0.5m AHD has only a minor impact on peak levels compared to 0% blockage and the existing channel dimensions. In 100% blockage of the culverts and filling the channel to 1m AHD the impacts are much larger, affecting the two golf courses and in Taren Point adjacent to Woolooware Bay and on the west side of Captain Cook Drive opposite Endeavour Road.

8.2.10. Flood Compatible Fencing

DESCRIPTION

All fencing around properties will have an impact on flooding depending upon their type and structural integrity. In mainstream flooding areas fencing may be destroyed but in overland flow areas this is less likely due to the shallow depths (generally less than 0.5m) and low velocities (generally less than 2m/s). The traditional paling fencing might be typically 50% permeable but the newer colorbond fencing may be less than 10% permeable. Some brick or metal fencing are nearly 100% impermeable and will not fail with 1m or even greater depth.

In some instances, residents install impermeable fencing to prevent inundation of their property. This can become a significant issue with neighbours who may receive diverted flows. As fencing is generally assumed to not require Council approval most landowners do not consider flooding in the decision-making process to install new fencing.

Flood levels can therefore possibly be reduced if flood compatible fencing is introduced with the aim of establishing a continuous and relatively unrestricted flow path through private property. Photo 9 indicates how fences can fall over in a flood and an example of flood compatible fencing.

Photo 9: Fences Damaged in a Flood and Flood Compatible Fencing

DISCUSSION

Flood compatible fencing can be undertaken within the regulatory framework as part of Council requirements to develop the property or on a voluntary basis. Several councils require flood compatible fencing on new developments or rebuilds but few (if any) landowners are likely to undertake this voluntary. Thus, to be undertaken on a voluntary basis some form of financial or other inducement will be required. The process for fence approvals that impact on flooding and consideration of potential voluntary fence modification schemes is also provided in Appendix D.

Whilst an excellent concept from a flooding perspective the introduction of flood compatible fencing raises several issues. Firstly, if the fence is jointly owned the adjoining neighbour may object for security reasons, because they will receive more floodwaters or for other reasons. It may therefore be difficult to achieve in many locations. Secondly, if the current fencing acts as a part hydraulic barrier, then installing flood compatible fencing will reduce flood levels upstream and increase flood levels in downstream properties. There would also be maintenance issues and whether the fence would require a positive covenant on the land title.

Preliminary hydraulic modelling of installing flood compatible fencing was undertaken but this raised many issues which could not be adequately resolved within the scope of the project. The main benefit was the reduction in external damages which is not as important as reducing above floor damages. Above floor damages are based on one flood level and one assumed floor level within a property and this is not rigorous enough for the type of assessment required to assess this measure, as no account is taken of the floor level at the rear or side of the house.

Visual inspection of fences indicates that fences in floodplains are problematic in that they can alter flow behaviour in unexpected and deleterious ways. They can retain floodwaters, divert floodwaters or collapse under hydraulic pressure, each situation causing localised increases in flood hazard which are not predicted by current flood models and may vary between events.

Voluntary fence modification is a means to incentivise property owners to modify boundary fences to make them flood compatible to ensure a more natural flow regime that reduces risk for both upstream and downstream property owners (if a continuous flow path is created).

For such a scheme to be established and operate the following issues need to be addressed.

- Identify and prioritise eligible properties (do fences need to be mapped beforehand?).
- Confirm development approval pathways – DA or CDC.
- Confirm implications of Dividing Fences Act 1991.
- Process for establishing a restrictive covenant or a compensated covenant on the modified fence.
- Contract arrangement between Council and property owner(s).
- Scheme marketing.
- Possible integration with voluntary house raising and flood proofing schemes (prioritisation, equity, etc).
- Consider if scheme is to exclude ‘interior’ fences such as pool fences, duplex boundary fences, fences bordering Council land, etc.

- Need for trial to test participation, administration, etc.
- Option should be workshopped with people beyond Council staff and the FMC.

RECOMMENDATIONS

Regulatory and voluntary flood compatible fencing is supported but the methodology of how it can be undertaken requires further investigation. A pilot scheme could be undertaken in the Woolooware Bay catchment for an approximate cost of $70,000.

8.3. Response Modification

8.3.1. Flood Warning

DESCRIPTION

It may be necessary for some residents to evacuate their homes during or following a major flood, though there are no records of this occurring in the Woolooware Bay catchment.

The amount of time for evacuation depends on the available warning time. Providing sufficient warning time has the potential to reduce the social impacts of the flood as well as reducing the strain on emergency services.

Flood warning and the implementation of evacuation procedures by the SES are widely used throughout NSW to reduce flood damages and protect lives. Adequate warning gives residents time to move goods and cars above the reach of floodwaters and to evacuate from the immediate area to high ground. The effectiveness of a flood warning scheme depends on:

- the maximum potential warning time before the onset of flooding.
- the actual warning time provided before the onset of flooding. This depends on the adequacy of the information gathering network and the skill and knowledge of the operators.
- the time required to complete a safe evacuation.
- the flood awareness of the community responding to a warning.

For smaller catchments a Severe Weather Warning is provided by the BoM, but this is not specific to a particular catchment.

DISCUSSION

The BoM is responsible for flood warnings on major river systems such as the Georges River. Flood warning systems are based on stations which automatically record rainfall or river levels at upstream locations and telemeter the information to a central location. This information is then provided to the SES who undertake evacuations or flood damage prevention measures (sand bagging or raising goods).

References 10 to 17 provide background detail regarding flood warnings, emergency planning and related issues.

The benefit cost ratio of flood warning systems depends on the cost to install or upgrade an existing system and the benefits that accrue in terms of a reduction in tangible and intangible damages. The reduction in tangible damages is less important than the reduction in intangible damages (safe and easy evacuation to high ground) which cannot readily be incorporated in a traditional benefit cost assessment. Also, there is only a limited amount of tangible damage reduction that is possible as damage to the building fabric, floor coverings, kitchen cabinets and other fixed items cannot be mitigated.

Flooding in the study area occurs relatively quickly (within two hours) and residents may potentially be caught unaware. Water level gauges that emit an alarm once a certain level is reached have been installed in other catchments of similar size. The main issues with these gauges are vandalism, maintenance and the ability or willingness of residents to respond accordingly and are probably only suitable in areas of high risk to life. To be successful the alarm must occur relatively frequently so that most residents have heard it and responded.

Flooding warning is a critical component of any flood emergency response system. Clear and timely flood warnings give flood-affected property owners the ability to prepare for the onset of flooding and so reduce risk to life and property. Current warning times from the BoM are at best around six hours, which are too high to be effective in overland flooding situations like the Woolooware Bay catchment which has critical storm durations of around 2 hours.

Consideration should be given to establishing a flood warning system that integrates the operation of current Sydney Water pluviometers within the BoM flood warning system. This system should ideally be established for the entire Sutherland Shire but could be piloted in the Woolooware Bay catchment.

There are three Sydney Water pluviometers surrounding the Woolooware Bay catchment that could be linked to a system which sends pre-recorded messages to registered mobile phones or other devices. Tailored warnings could be automatically sent based on the pluviometer readings exceeding some pre-set intensity and rainfall depth. To be successful the warnings must be provided to give sufficient time for property owners to take appropriate action, such as installing temporary flood barriers, raising valuable possessions or to self-evacuate.

RECOMMENDATIONS

The greatest improvement in the accuracy and ability to respond to any flood warning predictions generally only occurs following major flood events. It is imperative therefore that a post flood assessment report be prepared following each future flood event with particular emphasis on the adequacy and accuracy of how residents and emergency services responded.

The catchment is too small with a very quick response time (two hours or less) for a sophisticated flood warning system to be installed. However, the BoM is continually working on improving its Severe Weather Warnings and in time it may be appropriate to link these to SMS on mobile phones in the area. If the event occurs at night when mobile phones are not on or cannot be heard this would provide nil benefit.

In summary, whilst a sophisticated flood warning system is currently not viable for the Woolooware Bay catchment it is important that this measure is still pursued as technological advancements may produce a system that will provide a benefit. Sophisticated flood warning system are currently being developed for larger catchments in Sydney (Parramatta River). The approach taken and the results in an actual flood will provide the basis for further investigation in the Woolooware Bay catchment in the future.

An approximate cost to investigate the feasibility of a flood warning scheme is $60,000.

8.3.2. Flood Emergency Management

DESCRIPTION

As mentioned in Section 8.3.1, it may be necessary for some residents to evacuate their homes in a major flood. This would be undertaken under the direction of the lead agency, the SES. Some residents may choose to leave on their own accord based on flood information from the radio or other warnings and may be assisted by residents. The main problems with all flood evacuations are:

- They must be carried out quickly and efficiently.
- There can be confusion about 'ordering' evacuations, with rumours and well-meaning advice from other residents taking precedence over official directions which can only come from the lead agency, the SES.
- They are hazardous for both rescuers and the evacuees.
- Residents are generally reluctant to leave their homes, causing delays and placing more stress on the rescuers.
- People (residents and visitors) do not often appreciate the dangers of crossing floodwaters.

DISCUSSION

The SES has the skills and experience to undertake the necessary evacuations should they be required. However, during major storm events it is likely that all emergency services in the local area will be fully occupied, and the SES should not be relied upon for immediate assistance.

A key part of any flood emergency is the recovery arrangements, a well thought out and carefully managed recovery will ensure that residents and the community are able to be "back on their feet" as quickly as possible. This phase is very important and requires input from many different authorities.

Emergency response to flooding in the Sutherland Shire is managed under the SES Georges River and Woronora River Local Flood Plan. This plan is presented in several volumes and is currently (2022) being updated by the SES. The findings from this FRMS&P will be provided to the SES to help inform the update to the local flood plan.

Given the short flood warning times, the ability of emergency services to respond to major overland flooding in the catchment is limited. Resources are likely to be directed to managing road closures and responding to storm damage or risk to life issues, rather than evacuation or property protection.

Accordingly, flood emergency management should be focussed on self-reliance and self-evacuation. Specifically, this flood emergency management should target improving community flood awareness and improving the capability of flood affected property owners to prepare for and appropriately respond to flooding. Where appropriate buildings should have an up-to-date flood emergency plan.

Community flood awareness measures should link to current flood related development controls that seek to allow for shelter-in-place where floor levels are at or above the PMF. They should also link to the promotion of property modification measures such as property drainage and landscaping that aim to divert overland flows away from and/or around buildings (subject to not causing unacceptable flood impacts on neighbouring properties).

Shelter-in-place (i.e., stay home and wait out the flood) is an alternative approach to self or SES assisted evacuation. This is a problematic issue within the floodplain management field as shelter-in-place is generally not supported by the SES though most experts would say that it is probably safer than evacuation from the building (horizontal evacuation) in flash flooding environments. Intensification can generally only be allowed if people are able to safely shelter-in-place above the PMF as all roads will be inundated and dangerous to access in even small events, such as Captain Cook Drive.

The issues regarding approving developments in urban areas that rely on shelter-in-place, as opposed to horizontal evacuation include:

- Are the design floor levels at the PMF?
- There must be consultation with the SES on shelter-in-place versus deliberate entrapment.
- Is there an adequate flood emergency response plan?
- Distinguishing between residents, workers, and visitors / customers in the building.

Locations where shelter-in-place might be considered include:

- Little to no flash flood warning.
- Realistically little to no SES support.
- Short flood duration (less than 2 hours).
- Low community flood awareness and resident tendency to stay and protect.
- Considerable increase in flood risk moving from the house to outside.

The most important issue is to ensure that all residents are fully aware of the risks associated with flooding and this is addressed in Section 8.3.3.

RECOMMENDATIONS

The SES should ensure that the required response for the study area is up to date and includes feedback from recent flood events. Priority should be given to the implementation of this process once completed, which will continue to involve ongoing community education and awareness.

For many residential and commercial buildings in the Woolooware Bay catchment the most viable means of emergency management in a flood is to shelter-in-place due to the relatively short available warning time (typically less than 3 hours). Venturing outside will likely expose people to additional risk to life issues. In an emergency people should rely upon the emergency services for assistance rather than risk their own life.

Flood emergency plans for appropriate buildings are supported.

8.3.3. Public Information and Raising Flood Awareness

DESCRIPTION

The success of any flood warning system, damage / risk to life minimisation and any evacuation process depends on the following.

Flood Awareness: How aware is the community to the threat of flooding? Has the community been adequately informed and educated? How aware is the community of how this threat will be exacerbated with sea level rise and climate change induced rainfall increase?

Flood Preparedness: How prepared is the community to react to the threat of flooding? Do they (or the SES) have damage minimisation strategies (such as sandbags, raising possessions and a flood emergency plan) which can be implemented?

Flood Evacuation: How prepared are the authorities and the residents to evacuate (if required) households and businesses to minimise damages and the potential risk to life during a flood? How will the evacuation be done, where will the evacuees be moved to?

DISCUSSION

A community with high flood awareness will suffer less damage and disruption during and after a flood because people are aware of the potential of the situation. On river systems which regularly flood, there is often a large, local, unofficial warning network which has developed over the years and residents know how to effectively respond to warnings by raising goods, moving cars, lifting carpets, etc.

Photographs (of less importance with digital photography) and other non-replaceable items are generally put in safe places. Often residents have developed storage facilities, buildings, etc., which are flood compatible. The level of trauma or anxiety may be reduced as people have "survived" previous floods and know how to handle both the immediate emergency and the post flood rehabilitation phase in a calm and efficient manner. To some extent many of the above issues for the study area have already been addressed by the community because of previous floods (though these floods were of small magnitude).

The level of flood awareness within a community is difficult to evaluate. It will vary over time and depends on several factors including:

- *Frequency and impact of previous floods.* A major flood causing a high degree of flood damage in relatively recent times will increase flood awareness. If no floods have occurred, or there have been a few small floods which cause little damage or inconvenience, then the level of flood awareness may be low. As a result of the recent minor floods which caused minimal damage, the community generally has a low level of awareness at this time. It will decline as the time since the last flood increases and may increase because of community flood or climate change awareness programs.

- *History of residence*. Families who have owned properties for a long time will likely have established a considerable depth of knowledge regarding flooding and a high level of flood awareness. A community which consists predominantly of short lease rental homes will have a low level of flood awareness. Also, it is very likely that new residents will be aware from advice at the time of their property purchase (Section 10.7 certificate) or from neighbours after they move in. It is very unlikely that a new resident buying a house adjacent to an open channel will not be aware of the potential of flooding. However, in the upper parts of the catchment (upstream of the railway line) the potential of flooding is unlikely to be well understood.

- *Whether an effective public awareness program has been implemented.* A comprehensive catchment wide awareness program has not previously been undertaken by Council or the SES, though there have been articles in the national and local press regarding flooding. Most residents are generally more aware of flooding than in the past through social media or media outlets showing videos taken during floods (such as the Brisbane River January 2011 floods) as well as from the awareness of climate change.

For risk management to be effective it must become the responsibility of the whole community. It is difficult to accurately assess the benefits of an awareness program, but it is generally considered that the benefits far outweigh the costs. The perceived value of the information and level of awareness diminishes as the time since the last flood increases.

A major hurdle is often convincing residents that major floods (such as March 1975) will occur in the future. Many residents hold the false view that once they have experienced what they consider to be a large flood then another will not occur for a long time thereafter. This viewpoint is incorrect as a 1% AEP (1 in 100 year) event (or sometimes termed a 100-year ARI) has the same chance of occurring next year, regardless of the magnitude of the event that may have recently occurred. A similar analogy is after “tossing” a coin 5 times and coming up with “heads” each time, the chance of “heads” on the next throw is still 50:50.

Some NSW Councils (Rockdale, Pittwater, Maitland) have initiated catchment-wide flood awareness strategies (for residential and commercial). For this study area a residential strategy is only recommended. Council and the SES have excellent information on flood awareness and other flood related and climate change information on their web sites. However, residents must be interested enough to access this information.

Council has also other comprehensive information on flooding on their web site. Raising community flood awareness is important for helping reducing risk to life and property. The following are some aspects of flood awareness that should be considered for the Woolooware Bay catchment.

- Opportunities or triggers for raising flood awareness include proactive campaigns by SES and Council, major stormwater drainage upgrades, preparation of a site-specific flood emergency response plan as part of re-development, and actual flooding (not necessarily within the Woolooware Bay catchment).

- Flood awareness programs could prioritise properties based on the degree of above floor affectation and the overall risk to life and property.
- Flood awareness measures should broadly explain flooding mechanisms and behaviour i.e., flooding is not just from overflowing creeks or coastal inundation, and that the stormwater drainage network has little influence on overland flood behaviour.
- Where buildings on flood affected properties have floor levels above the PMF and the building is structurally resistant to flooding, then property owners should be encouraged to shelter-in-place.
- Flood awareness programs could acknowledge that although newly developed buildings are in most cases unlikely to experience above-floor flooding, open space around the building will remain flood affected.
- Where buildings on flood affected properties have floor levels below the PMF, then property owners should be offered practical but general options on how to reduce risk. For example, property modification measures such as drainage and landscaping, temporary flood protection barriers such as sandbags and boards, wet and dry flood proofing, storage of possessions (particularly in garages) above floodwaters, preparation of flood emergency response plans, redevelopment, etc.
- Flood awareness programs should attempt to encourage neighbouring flood-affected property owners to work together for mutual support, sharing of flood information and resources, etc.
- Need to acknowledge that horizontal evacuation is a vexed issue. SES traditionally encourages property owners to self-evacuate outside the floodplain, however short warning and response times plus limited organisational capability make horizontal evacuation difficult in this instance. It is suggested that many flood-affected property owners would likely stay to defend buildings, even with above floor flooding. Horizontal evacuation is also likely to be impeded by road closures and heavy traffic and could be a greater risk, particularly if attempting to cross main flow paths at the Kingsway / Gannons Road / Denman Avenue, or along Captain Cook Drive.
- Community flood awareness programs must be supported by clear, up-to-date, and easily accessible information on flooding and flood emergency response. Information would include flood maps on Shire Maps, access to property-specific flood information sheets, FloodSafe brochures and fact sheets / tips / advice on the measures listed above.
- Community flood awareness programs must also be linked to or integrated with other flood risk management measures such as flood warning measures, voluntary flood proofing schemes, voluntary fence modification and redevelopment options.

RECOMMENDATIONS

Based on an indicative review, most residents within the study area have a low level of flood awareness and preparedness on account of the history of flooding and that there are no significant open channel systems outside the two golf courses. As time passes since the last significant flood, the direct experience of the community with historical floods will diminish. It is important that a high level of awareness is maintained through implementation of a suitable Flood Awareness Program that would include Floodsafe brochures as well as advice provided on the Council and SES websites. Council and the SES are both active in updating their flood information for all catchments and this should continue. Table 16 provides examples of various flood awareness methods that can be employed.

Table 16: Flood Awareness Methods

Method	Comment
Letter/pamphlet from Council	These may be sent (annually or biannually) with the rate notice or separately. A Council database of flood liable properties/addresses makes this a relatively inexpensive measure which can be effective if residents take the time to absorb and apply the suggestions. The pamphlet can inform residents of ongoing implementation of the Flood Risk Management Plan, changes to flood levels, climate change or any other relevant information.
Council website	Council should continue to update and expand their website to provide both technical information on flood levels as well as qualitative information on how residents can make themselves flood aware. This would provide an excellent source of knowledge on flooding within the study area (and elsewhere in the LGA) as well as on issues such as climate change. It is recommended that Council's website continue to be updated as and when required.
Community Working Group	Council could initiate a Community Working Group framework (undertaken in other catchments elsewhere) and this would provide a valuable two-way conduit between the local residents and Council.
School project or local historical society	This provides an excellent means of informing the younger generation about flooding, waterway management and climate change. It may involve talks from various authorities and can be combined with other related topics such as water quality.
Displays at key locations or similar	This is an inexpensive way of informing the community and may be combined with related displays.
Historical flood markers and flood depth markers	Signs or marks can be prominently displayed on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators advise of potential hazards. These are inexpensive and effective but in some flood communities not well accepted as it is considered that they affect property values.
Articles in local newspapers	Ongoing articles in the newspapers will ensure that the flood and climate change issues are not forgotten. Historical features and remembrance of the anniversary of past events are interesting for residents.
Collection of peak water level data from future floods	Collection of data (photographs) assists in reinforcing to the residents that Council is aware of the problem and ensures that the design flood levels are as accurate as possible. This might also include establishment of peak water level marker poles and which house floors are inundated.
Types of information available	A recurring problem is that new owners consider they were not adequately advised that their property was flood affected on the 10.7 Certificate during the purchase process. Council may wish to advise interested parties, when they inquire during the property purchase process, regarding flood information currently available, how it can be obtained and the cost. This information also needs to be provided to all tenants and visitors who may rent for a period. Some Councils have conducted "briefing" sessions with real estate agents and conveyancers.
Establishment of a flood affectation effects database	A database would provide information on (say) which houses require evacuation, which public structures will be affected (e.g., telephone or power cuts). This database should be reviewed after each flood event and is already being developed as part of this FRMS&P. This database should be updated following each flood with input from the community.
Flood preparedness program	Providing information to the community regarding flooding helps to inform it of the problem and associated implications. However, it does not necessarily adequately prepare people to react effectively to the problem. A Flood Preparedness Program would ensure that the community is adequately prepared. The SES would take a lead role in this.
Develop approaches to foster community ownership of the problem	Flood damages in future events can be minimised if the community is aware of the problem and takes steps to find solutions. The development of approaches that promote community ownership should therefore be encouraged. For example, residents should be advised that they have a responsibility to advise Council if they see a problem such as debris blockage or such like. This process can be linked to water quality or other water related issues including estuary management. The specific approach can only be developed in consultation with the community. Consideration and reference should be made to engage the community as per the community engagement International Association for Public Participation spectrum framework and associated methods and activities. These seek to promote and improve the practice of public participation or community and stakeholder engagement, incorporating individuals, governments, institutions, and other entities that affect the public interest.

The specific flood awareness measures that are implemented will need to be developed by Council considering the views of the local community, funding considerations and other awareness programs within the LGA. The details of the exact measures would need to be developed in consultation with affected communities.

An indicative cost to develop a community awareness and resilience program is $70,000.

8.3.4. Improved Flood Access, Road Closures and Notifications

DESCRIPTION

Access in times of flood is important in all flood liable areas to ensure that residents can travel safely to higher ground. Section 5.5 and Table 11 indicate the extent of road overtopping in times of flood.

DISCUSSION

In urban areas flood access is not as critical as in rural areas as the duration of closure is short (less than 3 hours) and there are generally alternative routes. Also, in urban areas vehicle incidents (breakdowns and accidents) as well as the effects of storm damage (fallen trees) mean that it is not possible to guarantee that any road (whether inundated or not) will be passable in a severe storm event.

In rural areas early warning of road closures is important to ensure drivers make informed choices. In urban areas the short available warning time means that early warning is not possible, and drivers must rely on their own experience (heavy rain falling) or listen to the media. Road depth indicators are placed on many roads in rural areas but less so in urban areas. These may be appropriate on Captain Cook Drive and on other frequently inundated roads.

On minor roads the enlarging of culverts or raising of the road would ensure less frequency of overtopping. These works should be considered when upgrading or any works are proposed on flood liable routes.

RECOMMENDATIONS

No specific road raising works to improve flood access are proposed as part of this study. Depth indicators at road crossings are an appropriate cost-effective measure to advise drivers of the depth of flood waters. However, advice from the SES is that drivers should not enter any flooded road crossing as even at shallow depths vehicles can be moved and potentially be swept into floodwaters or crashing thus presenting a significant risk to life.

An indicative cost to install flood depth indicators at key locations is $20,000.

8.4. Property Modification

Property modification measures modify the existing land use and development controls for future development. This is generally accomplished through such means as flood proofing, house raising or sealing entrances, strategic planning such as land use zoning, building regulations such as flood-related development controls, or voluntary purchase / voluntary house raising.

8.4.1. House Raising

DESCRIPTION

House raising involves lifting the main habitable floors above a designated design level (typically the 1% AEP or PMF). It has been widely used throughout NSW to eliminate or significantly reduce above floor inundation particularly in low hazard areas of the floodplain, albeit in limited overall numbers. However, it has limited application as it is not suitable for all building types, or properties in high hazard areas (where the house may be washed away).

The NSW State Government has provided guidelines for voluntary house raising schemes in Reference 18.

Voluntary house raising as a mitigation measure has been successful in the past in areas where regular mainstream flooding occurs frequently, and programs have been implemented on the Georges River and in many rural areas. However, as these older houses are nearing the end of their useful life, re-building has become comparatively much cheaper than in the past and landowners want modern features in their houses (en-suite, air conditioning, several bathrooms) there are few opportunities for house raising to be a viable measure. This trend has been further increased with developers and landowners seeing the opportunity to re-develop an old house as a dual occupancy.

DISCUSSION

The benefit of house raising is that it eliminates above floor flooding and consequently reduces flood damages. It is best suited to non-brick, single storey houses. House raising also provides a safe refuge during a flood, assuming that the building is suitably designed for the water and debris loading. However, the potential risk to life is still present if residents choose to enter floodwaters or are unable to leave the house during larger floods than the design flood, particularly in high hazard areas. Ideally floor levels should be raised to be above the level of the PMF and therefore areas with deep flood depths during this event may not be suitable for house raising.

An indicative cost to raise a house is $80,000 though this can vary considerably depending on the specific details of the house. Additionally, the type of construction of a house can make raising unfeasible, either technically or economically and not all buildings are viable for raising for the following reasons:

- It is more cost effective to construct a new house.
- Generally, only single storey houses can be raised.
- Generally, only timber, fibro and other non-masonry construction can be raised.
- Generally, only pier and non-slab on ground construction can be raised.
- There can be many additional construction difficulties (brick fireplace, brick garage attached to house, awnings or similar attached to the house).

House raising as a flood mitigation option in the Woolooware Bay catchment is unlikely to be a viable due to the lack of suitable buildings (it is not viable for brick buildings). However, this measure is always available for residents to pursue if they are interested.

The floor level database prepared as part of this study (Section 3.1) did not include identification of houses that may be suitable for house raising, thus suitable individual houses cannot be identified from the database. However, experience in other areas has shown that generally all the houses that could be raised easily have been raised, the remaining ones are either too difficult to raise, have reached the end of their life or the owners do not wish to enter via steps.

Experience has also shown that many owners of houses that potentially could be raised are not interested in undertaking the works for reasons such as:

- They do not want an elevated entry to their house.
- The house is old without modern facilities and re-development has meant that developers or landowners are always interested in purchasing older buildings or doing the works themselves to re-develop as dual occupancies or as a single dwelling.
- Owners will have to live elsewhere during the construction phase (possibly 3+ months).
- Owners are unwilling to pay the costs not funded under the grant scheme (attached garage or fireplace).
- Whilst it is possible to raise most single storey non brick houses many owners consider the inconvenience too much of a burden.
- Flood insurance is now available.
- The owners of any low-lying building that has experienced frequent above floor inundation over the past 30+ years will generally have addressed the issue by modifying the entrance to the building (constructing minor walls or landscaping) as the above ground water depths are shallow (less than 0.3m) and thus a local measure can eliminate or significantly reduce the problem.

The traditional approach to house raising in this area will not be successful in significantly reducing the number of houses (if any) with above floor inundation. An alternate approach considered is termed “incentivised early redevelopment”. This approach involves funding homeowners to redevelop their home immediately rather than waiting for it to occur with the passage of time. This approach has not been undertaken previously in NSW and would require extensive investigation to determine its viability in the Woolooware Bay catchment. There are many issues and one of the main ones is the equity issue of providing funding to landowners which will then increase their property value at the public’s expense.

RECOMMENDATIONS

In the Woolooware Bay catchment with high property values (the medium house price is nearly $2 million) and for the reasons listed above, there is unlikely to be any house where the owner will accept house raising. No houses have been identified as suitable for house raising based on a Google Street View and limited “drive past” inspections.

Incentivised early redevelopment has been considered but would require extensive investigation to determine its viability in the Woolooware Bay catchment. An indicative cost to assess the feasibility of this scheme is $60,000.

8.4.2. Voluntary Purchase

DESCRIPTION

Voluntary purchase involves the acquisition of high-risk flood affected properties, particularly those frequently inundated in high hazard areas. Demolition of the residence would then occur to remove it from the floodplain. Removal of properties can help to restore the natural hydraulic capacity of the floodplain.

The NSW State Government has provided guidelines for voluntary purchase schemes in Reference 19.

DISCUSSION

Voluntary purchase is mainly used in hazardous areas of the floodplain as a means of removing isolated or remaining buildings over the long term to free both residents and potential rescuers from the danger and cost of future floods. The land is given over to public space and should be rezoned as an appropriate use such as E2 Environmental Conservation or similar in the LEP so that no future development can take place.

It should be noted that voluntary purchase has been successfully applied in the Sutherland Shire by the NSW Government as part of the Shackels Estate Voluntary Acquisition Scheme within the Woronora River floodplain. Voluntary purchase has also been applied for other parts of the Georges River floodplain and has also been considered for overland floodplains like the Canley Corridor in the Fairfield LGA. Voluntary purchase is usually only considered when the flood hazard is unacceptably high, flood damages are high and there are few if any other feasible FRM measures to reduce risk. Voluntary purchase of all flood liable buildings within the catchment is not viable due to the extremely high cost per property (>$2 million) and the likely adverse social impact.

Voluntary purchase is an effective strategy where it is impractical or uneconomic to mitigate high flood hazard to an existing property and it is often employed as part of a wider management strategy. Government funding for voluntary purchase schemes can be made available through the Floodplain Development Program if several complying criteria are met.

A Google Street View and limited “drive past” inspections have indicated that there are no houses in the catchment which are considered high risk and frequently inundated in high hazard areas and thus suitable for voluntary purchase.

RECOMMENDATIONS

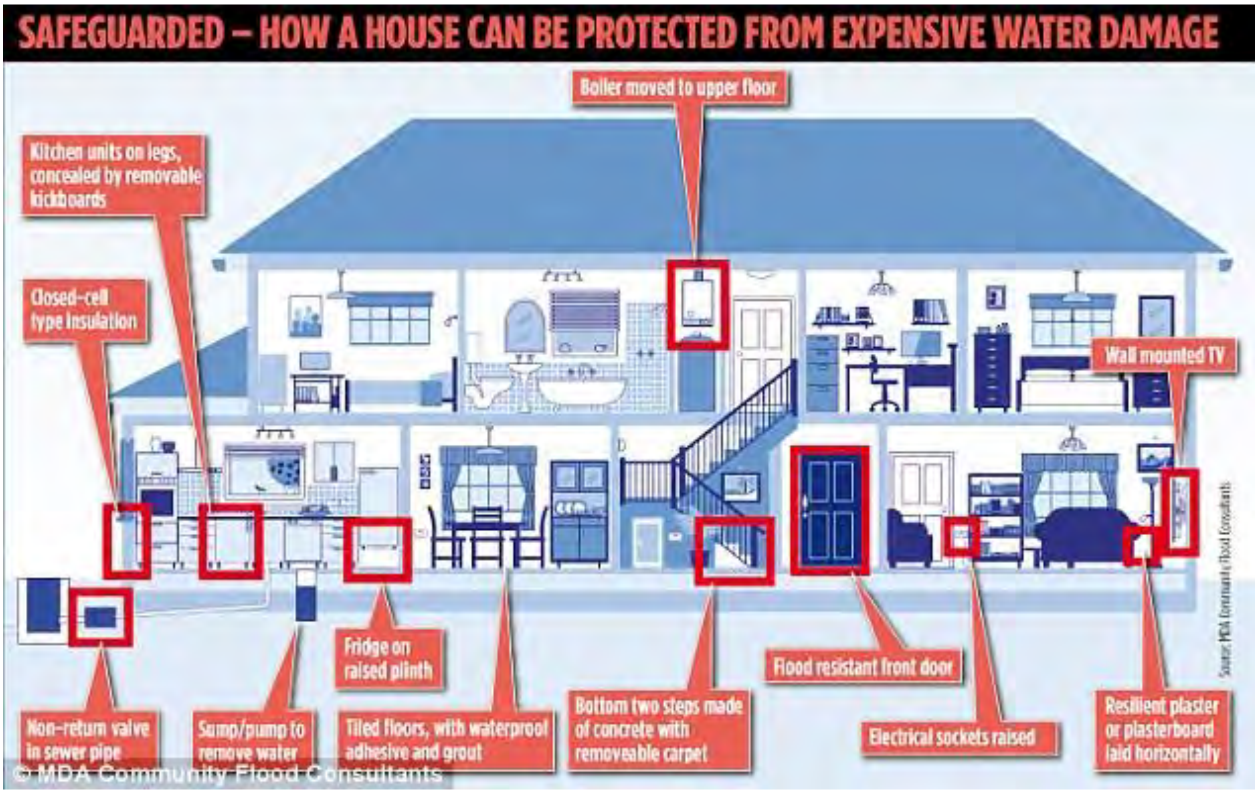
No houses have been identified as suitable for voluntary purchase.

8.4.3. Flood Proofing

DESCRIPTION

Flood proofing is often divided into two categories: wet proofing and dry proofing. Wet proofing assumes that water will enter a building and aims to minimise damage and/or reduce recovery times by choice of materials which are resistant to flood waters and facilitate drainage and ventilation after flooding. Dry proofing aims to totally exclude flood waters from entering a building and is best incorporated into a structure at the construction phase. Diagram 10 indicates how flood proofing measures can be incorporated into a typical house.

Diagram 10: Examples of Flood Proofing in a Typical House



There is also a distinction between voluntary flood proofing of existing inundated buildings and Council's regulatory flood proofing required as part of redevelopment. This section only considers voluntary flood proofing of existing inundated buildings.

As an alternative to retrofitting permanent flood proofing measures to existing properties, individual temporary flood barriers can be used. These include sandbags, plastic sheeting and other smaller barriers which fit over doors, windows and vents and are deployed by the occupant before the onset of flooding. It may also include measures to divert flood waters away from the building such as small walls or regrading of driveways.

DISCUSSION

Retrofitting permanent flood proofing measures can be difficult and costly, and therefore permanent flood proofing is best implemented during construction. As such, flood proofing can be stipulated within Council's DCP as requirements for structures below the FPL.

Temporary flood barriers such as sandbagging and floodgates can be a cheaper option for existing properties and can be useful where there is frequent shallow flooding, although it relies on someone to implement it and therefore requires adequate flood warning times. Sandbagging, often used in conjunction with plastic sheeting, can provide a solution for dealing with flooding in smaller areas and at individual properties. Whilst sandbags and plastic sheeting seldom prevent the ingress of floodwaters entirely, they can substantially decrease the depth of over floor flooding and the foulness of floodwaters, thus aiding the clean-up process.

Sutherland Shire Council supports flood proofing principles for existing development and structures which are below the FPL to reduce flood damages. This includes considering flood compatible material to reduce impacts during a flood event, ease clean up afterwards, and maintain structural integrity; and locating electrical fixtures and sewer services above the FPL.

Whilst it is a requirement of the Floodplain Development Manual (Reference 2) that new residential properties have their flood levels above the design level (typically the 1% AEP event plus a freeboard), commercial properties are not subject to such a requirement unless stipulated by Council, as they are by Sutherland Shire Council.

Consideration of suitable materials, electrical and other service installations, and efficient sealing of any possible entrances for water are not stipulated in Council's DCP. It would be appropriate for Council's DCP to provide links to best practice flood proofing guidelines. It is recommended that planning controls allow some flexibility in the type of proofing adopted but these would need to be approved by the certifying body.

Over the last 10+ years the Woolooware Bay catchment has a relatively high rate of house rebuilding and upgrading. This has increased in 2020 due to very low interest rates and Covid related issues such as:

- Residents working from home wanting an improved home office.
- Low interest rates to obtain loans.
- Residents having "spare capital" due restrictions on travel overseas and internally.
- Other less defined Covid related issues.

There also have been considerable advances in the principles and approaches to flood proofing properties, both in the retrofitting and construction phases, to residential properties. Two key guidelines are:

- *Reducing Vulnerability of Buildings to Flood Damage: Guidance on Building in Flood Prone Areas* (Reference 20).
- *Flood Resilient Building Guidance for Queensland Homes* (Reference 21).

Flood proofing in overland flow catchments has the potential to be cost-effective at reducing flood damages due to the shorter duration and shallower depths of flooding typically experienced. Council's DCP should include requirements for the use of flood compatible building materials and to reference the best practice guidelines appliable at the time. However, further opportunities are available to retrofit existing at-risk residential properties or provide advice regarding how to minimise future flood damages.

Another key question is for redevelopment where the building is retained and these floor levels are below the FPL, to what extent should Council require this control to be applied? This issue should be investigated as part of the DCP review, and the outcome would likely need to consider the relative cost of damages and the overall cost of the works.

Recent retrofitting programs include Brisbane City Council's *Flood Resilient Homes Program* which aims to increase the uptake of flood proofing for high risk (50% AEP) properties (see https://www.citysmart.com.au/floodwise/), and Logan City Council's pilot resilient homes program. Both programs involved evaluating existing properties at high risk of flooding for options to make them more resilient though the use of home assessments and engaging with at-risk homeowners about flood risk and management strategies. The Brisbane City Council program then provides financial assistance to homeowners to implement the recommended strategies, with the Logan City Council program providing homeowners with an assessment report that they could use in the future to make the necessary modifications including house raising.

Analysis of the property database (Table 7) identified 47 houses shown to be at risk of above floor inundation in the 20% AEP event. These properties could form part of a pilot retrofit flood proofing program or house raising program in the study area, whereby building assessors review the property, including a ground truthing of flood risk, and provide advice to landowners on ways to make their home more resilient to flooding. This program could also be used as the evidence base to develop a Flood Resilient Housing Guideline specific to the Sutherland Shire LGA, which considers the source and scale of flood risk, typical housing stock features and characteristics, the visual and amenity aspects specific to the LGA. Reference to the guideline could then be included in Council's DCP.

RECOMMENDATIONS

Voluntary flood proofing should not be approved to meet Council's flood planning development controls. However, they can be applied as a retrofit measure for an existing flood liable development or to provide additional protection to above the minimum standards.

With the relatively high rates of redevelopment in the catchment, for reasons such as low interest rates and Covid-19, combined with significant advances in approaches to flood proofing, the introduction of a Flood Resilient Housing Guideline specific to the Sutherland Shire LGA should be evaluated. Council will accept / require flood proofing for certain types of redevelopments where the existing building is retained, and these floor levels are less than the required FPL.

An indicative cost to investigate the feasibility of a voluntary flood proofing program is $60,000.

8.4.4. Land Use Zoning

DESCRIPTION

Appropriate land use planning can assist in reducing flood risk and ensure development on flood affected areas is flood compatible. Appropriate land use controls in flood affected areas can prevent inappropriate development from occurring and thus reduce flood risk. Land use zones are generally governed by a LEP. To make any significant changes to the provisions of a LEP, a planning proposal must be prepared.

DISCUSSION

Zoning can be a powerful tool in reducing flood damages, however, overly restrictive zoning can discourage redevelopment that is more flood compatible causing areas to degenerate over time. Progressive zoning can be used to encourage long term change in flood resilience. The current land use zones for the Woolooware Bay catchment are in line with an acceptable flood risk. No changes to the current land use zoning are recommended from a floodplain management perspective.

Although redevelopment of buildings with above-floor inundation should be encouraged to reduce tangible direct and indirect flood damages, intensification via up-zoning, which will place more people into the floodplain and potentially increase intangible and indirect damages should be avoided. The following three areas were identified as being of concern in this regard.

- Edinburgh Close / Woolooware Road flow path, Woolooware.
- Flow path upstream and downstream of Dwyer Reserve, Caringbah South.
- Cawarra Road / Carabella Road flow path, Caringbah.

RECOMMENDATIONS

Potential changes in land use zoning that increase the density of population must consider whether these will significantly increase the risk to life, intangible damages, demands on the SES in flood times and other adverse consequences.

8.4.5. Flood Planning Levels

DESCRIPTION

Flood Planning Levels (FPLs) are an important tool in floodplain risk management. Appendix K of the Floodplain Development Manual (Reference 2) provides a comprehensive guide to the purpose and determination of FPLs. The FPL provides a development control measure for managing future flood risk and is derived from a combination of a flood event and a freeboard. The Manual states that, in general, the FPL for a standard residential development would be the 1% AEP event plus typically a 500 mm freeboard.

The purpose of the freeboard, as described in the Manual, is to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of the FPL, is provided, given the:

- Uncertainty in estimating flood levels.
- Differences in water level because of local factors.
- Potential changes due to climate change.

The FPL is used in planning control primarily to define minimum habitable floor levels but also for other factors such as evacuation, storage of hazardous goods, etc. Different FPLs are applied for different land uses / structures in urban areas.

DISCUSSION

The standard FPL for residential development as defined in the Manual is the 1% AEP event plus 500 mm freeboard. Depending on the nature of the development and the level of flood risk, individual FPLs can be adopted for a local area within a greater floodplain area. For example, in areas prone only to shallow overland flooding (not applicable in this catchment), application of the 500 mm freeboard can be excessive.

Selecting the appropriate FPL for a particular floodplain involves trading off the social and economic benefits of a reduction in the frequency, inconvenience, damage, and risk to life caused by flooding against the social, economic, and environmental costs of restricting land use in flood prone areas and of implementing management measures.

The FPL can be varied depending on the use, and the vulnerability of the building / development to flooding. For example, residential development could be considered more vulnerable due to people being present, whilst commercial development could be considered less vulnerable, or it could be accepted that commercial property owners are willing to take a higher risk. Less vulnerable development could therefore be prescribed lower floor levels but may then be subject to other controls, such as flood proofing, up to the level of the FPL. For developments more vulnerable to flooding (hospitals, schools, electricity substations, seniors housing, etc.) consideration should be given to events rarer than the 1% AEP when determining their FPL or situating those developments outside the floodplain where possible.

According to the Manual the *purpose of the freeboard is to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of a FPL (Flood Planning Level) is actually provided given the following factors*:

- Uncertainties in estimates of flood levels.
- Differences in water level because of local factors.
- Increases due to wave action from vehicles.
- The cumulative effect of subsequent infill development on existing zoned land.
- Climate change. This largely relates to rainfall increase as future sea level rise has been relatively accurately determined by the intergovernmental panel for climate change and should not be included within the 500mm freeboard. Council adopts a climate induced sea level rise in setting floor levels for properties adjacent to the Bay in addition to the 500mm freeboard. Currently possible climate change rainfall increases are assumed to be incorporated within the 500mm freeboard due to their relatively small magnitude (refer Figure B21 to Figure B28).

In a real flood some of these factors may reduce the flood level (local factors) or not apply at all (no wave action). For example, in a future 1% AEP event blockage (due to say fallen trees) may elevate the peak level just upstream. However, such an event would be considered as rarer than the 1% AEP as that type of blockage is an exception, as it would not always occur in every flood.

Observed flood levels in overland flow paths can be significantly higher than modelled levels due to flow obstructions such as fences, cars, sheds, etc. The influence of these obstructions depends on the type of obstruction and the flow behaviour. Obstructions and corresponding increases in flooding are more likely to occur in the upper to middle catchment where higher velocity flows pass through private property often parallel to buildings. Higher freeboards should therefore be retained in these areas despite the apparent shallow depths of flow. Flow along roads perpendicular to buildings, and lower velocity flows in the flatter, middle to lower catchment are less likely to be influenced by these obstructions but the depths of flow are likely to be greater than in the upper catchment.

There is no scientific reason for assuming a 500mm allowance for freeboard. In some locations (say Windsor on the Hawkesbury River) it could be argued that a greater freeboard should be applied as the PMF is several metres above the 1% AEP, thus 500mm represents only a relatively small increase in flood magnitude. At other locations a 500mm increase above the 1% AEP may approach the PMF level and thus represents a very large increase in flood magnitude. For simplicity a 500mm freeboard is adopted by nearly all Councils in NSW for mainstream flooding. Some Councils adopt a smaller freeboard when the depths of inundation in urban areas, with no defined creeks or channels, are shallow (less than 300mm). Freeboards are typically not applied to the PMF level due to the rarity of this event and might not be applied to more frequent floods (5% AEP) where adopted for design.

FPLs for Basement Car Parking: In the last 10+ years in Sydney there has been an increased construction of basement car parks for residential (unit and detached housing) as well as for commercial buildings. This is due to several factors including increased demand for off road parking, optimisation of the use of available land and reduced construction costs for the excavation work. Basement car parks represent a potential high cost of flood damage due to the number of cars present but more importantly a significant risk to life for drivers and passengers who may be present.

Floodwaters enter basements rapidly due to the wide and inclined entrance and there are examples of drivers attempting to exit through entering floodwaters. This potential flood damage and risk to life can be negated if appropriate entrance controls are implemented (requirement to elevate the entrance to above the PMF so no flood waters can enter). An example of a unit block car park inundated in Queensland and a car driving through a flooded basement car park (with a car driving through) during the November 2018 storm in Sydney are shown in Photo 10 (left and right respectively).

Photo 10: Inundated Basement Car Parks

A survey was undertaken of basements which possibly may be subject to inundation in the catchment and these are listed in Table 10 (shown on Figure 6) together with the maximum 1% AEP and PMF flood levels on the property. However, it should be noted that flood levels shown are not necessarily those that would occur at the entrance to the basement. A detailed site inspection would be required to establish the likely frequency of inundation of each basement. Inundation of basements was not considered in the flood damages assessment.

Most Councils which require FPLs for basement car parks nominate either the 1% AEP + 500mm or the PMF as the minimum driveway entry level. It is also important that all entry points to the basement (air vents, lift wells, fire doors) are to this level as these can be easily missed. Sutherland Shire Council requires a 200mm freeboard.

Variable FPLs: For residential developments the majority of NSW LGAs apply the 1% AEP + 500mm which is suggested in the Manual though there are exceptions. A common reason for reducing the 500mm freeboard is if there is a shallow depth of inundation (say 200mm) in the 1% AEP event and thus including a 500mm freeboard appears excessive as the resulting level may then exceed the PMF. This is common in wide relatively flat urban areas such as Woolooware Bay and occurs in several of the properties inundated in the PMF.

An approach adopted by the City of Sydney is to allow *"Two times the depth of flow with a minimum of 300mm above the surrounding surface if the depth of flow in the 1% AEP flood is less than 250mm".* Many developers argue for a reduced freeboard to comply with other planning requirements (maximum building height) and minimise costs.

Council might consider varying freeboards across the catchment. This is likely to be confusing for Council staff to manage, may introduce errors, will require additional effort to resolve and it is difficult, if not impossible, to justify the criteria as to why one area or property should have a different freeboard to its neighbour. It is recommended that Council continues to adopt a 500mm freeboard but where valid reasons are provided a variation will be considered.

FPLs for all Land Use Types: Currently DCP 2015, Chapter 40 only specifies FPLs for residential, non-residential and car parking spaces. A few Councils and in particular the City of Sydney provide FPLs for a range of land use types including business, schools, retail floors, aged care, and different types of external parking. Council should consider introducing FPLs for all types of land uses.

RECOMMENDATIONS

The Floodplain Development Manual (Reference 2) recommended FPL of the 1% AEP event plus 500mm freeboard for residential floors is appropriate for the Woolooware Bay catchment. Variations will only be considered where valid reasons are provided.

Minimum design flood levels for other land use activities should be adopted as part of a revised DCP.

8.4.6. Flood Planning Area

DESCRIPTION

The Flood Planning Area (FPA) is an area to which flood planning controls are applied. As part of the July 2021 flood planning update Council has been provided with a figure showing the properties inundated in the FPL event (1% AEP + 500mm) and in addition those properties inundated in the PMF and not in the FPL extent.

It is important to define the boundaries of the FPA to ensure flood related planning controls are applied where necessary and not to those lots unaffected by flood risk. Typically, and as per the Floodplain Development Manual, the FPA for mainstream flooding has been based on the flood extent formed by the 1% AEP event plus 500 mm freeboard, and therefore, extends further than the 1% AEP event. Planning controls are therefore applied to development which is not flooded in a 1% AEP event.

Flood risk precincts maps for the Woolooware Bay catchment are now publicly available on Shire Maps. The maps given a good overall representation of flood risk which is appropriate for a public website. More detailed property specific information of flood behaviour, hazard, hydraulic categories, etc, can be purchased from Council.

DISCUSSION

The FPA is used by Councils to identify or "tag" flood control lots. The tagging is undertaken to comply with the planning legislation regarding Section 10.7 certificates to ensure that appropriate flood related development controls are applied to:

- Minimise future flood damages.
- Minimise risk to life.
- Ensure future development does not worsen the existing flood problem.

Without tagging Council officers have no mechanism to identify properties which are at risk and prospective purchasers would not know the development constraints on the property they were about to purchase. The Floodplain Development Manual outlines the approach and some legal issues relating to identifying flood liable properties but provides little insight into the fine details of how this should be undertaken for overland flow areas.

A summary of the position of other Councils in NSW on flood tagging (noting that this is based on a limited dataset) is as follows:

- The identification of flood liable properties has been undertaken by some NSW Councils for over 20 years, although prior to July 2021 there were still some Sydney Councils that have not undertaken this process.
- Prior to the year 2000 properties that were identified were largely derived because of mainstream flooding. This is identified as overtopping of the banks of a river or creek such as the Woronora or Georges Rivers, though much smaller creeks were also included in areas that had experienced flooding in the past and were under development pressures.
- One of the first Sydney Councils to identify properties due to overland flooding (there is no precise definition of overland flooding) was Rockdale City Council circa 1999. Rockdale City (now Bayside Council) became probably one of the first Councils to complete this process for their LGA.
- There is no consensus among NSW Councils regarding the tagging of flood liable properties. Some Councils tag to the 1% AEP, some to the 1% AEP + 500mm freeboard and some tag for both categories using different words. In the past some Councils tagged to lower levels (say the 2% AEP), but this is now not current practice, and the consensus is the 1% AEP. Tagging to above the 1% AEP + 500mm prior to July 2021 was prohibited for residential properties unless there were special circumstances, but it could be applied for non-residential properties.
- The 2001 and subsequent 2005 Floodplain Development Manual introduced the need

for Councils to consider overland flooding in addition to mainstream flooding.

- Prior to July 2021 there was no consensus amongst Councils regarding the wording or information provided on the Section 10.7 (2) and (5) certificates.
- The climate change induced sea level rise (and consequent rise in flood level) has been adopted by some Councils and is under discussion by others. Few Councils have adopted a climate change induced rainfall increase in their planning controls.
- The staff and legal representative of the Council as well as the consultant engaged to undertake the flood studies have a significant bearing on the approach undertaken to property tagging by that Council. The State Government authority (DPIE) provides technical input and comment but do not stipulate a preferred approach.
- The Mid-Density Developments Pty Ltd v Rockdale Municipal Council Federal court case outcome highlighted the legal importance of Councils providing known flood related information to purchasers of properties in the floodplain.
- In the last few years, the availability of residential flood insurance and recent floods in urban areas (Newcastle in June 2007 and Brisbane in January 2011) has increased public awareness of flooding and particularly the potential implications of property tagging and information on the Section 10.7 certificates. In places this has resulted in higher insurance premiums in some areas.
- Over the last 15 years significant technological advances (GIS and 2 Dimensional hydraulic (2D) models employing ALS) have enabled more accurate and sophisticated property tagging approaches to be employed.
- The modelling and mapping of overland flow areas (such as Woolooware Bay) using 2D models has meant Councils must now address overland flow mapped areas.

Previously property tagging was undertaken manually using contours and flood levels from a hydraulic model. The use of 2D hydraulic models (they discretise the ground into grids) and ALS has meant that accurate flood extent mapping is possible. ALS is generally only accurate to ±0.15m (vertical) on hard surfaces (but with much less accuracy over vegetated or uneven surfaces) and ±1m horizontally. Mapping can therefore be undertaken directly from the results of a 2D hydraulic model.

The use of GIS/mapping software allows consideration of a minimum depth criteria as well as a % of the property inundated criteria. This is generally not a consideration for mainstream flooding but is important in overland flooding where the depths are relatively shallow across properties and the flat topography can mean that say a 0.1m increase in level transmits into several additional properties being inundated. Furthermore, in overland flood modelling the use of ALS and the method of obtaining a regular grid from a ground surface defined by ground levels at irregular spacing can cause anomalies (for example under heavy vegetation cover there is limited ALS coverage).

The Section 10.7 Planning Certificate is a certificate under Section 10.7 of the Environmental Planning and Assessment Act 1979. Planning Certificates give information on the development potential of a parcel of land including the planning restrictions that apply to the land on the date the certificate is issued. The legal requirements are that the.

- Section 10.7 (2) only requires the Council to include *"whether or not the Council has by* *resolution adopted a policy to restrict the development of the land because of the likelihood of land slip, bushfire, flooding, tidal inundation and subsidence or any other risks"*. A 10.7(2) certificate must legally be attached to a contract for the sale of the land.

- Section 10.7 (5) provides a broader range of information relevant to the land which may include additional advice on matters that relate to: exhibited draft DCPs, whether it is potentially contaminated land, and other relevant matter affecting the land of which Council may be aware.

There is no consistent approach between Councils regarding the wording or the details provided or not, in the Section 10.7, Part 2 or Part 5 certificate.

The following are the key principles that should be considered in applying a tagging approach:

- Defensible in the Land & Environment Court.
- In accordance with best practice.
- "Simple" to apply by Council (e.g., to nearest 0.1m).
- Approach should be understood by the public.
- Quantitative rather than qualitative approach to eliminate errors and can be replicated on all catchments in the LGA.
- Able to be modified if the need arises due to more accurate survey becoming available or where there is some justifiable complaint.
- The approach must be fully documented.
- The approach must be uniformly applied across the LGA.
- Council's legal representatives should review the proposed policy.

Several Councils in the past 10 years within the Sydney basin have experienced adverse public reaction to the introduction of flood related property tagging notably in overland flow areas.

With mainstream flooding there are few properties on the "cusp" of being tagged or not. With overland flooding this is not the case due to the relatively flat terrain and/or shallow depths of inundation. The idea of tagging is to ensure that the flood risk on the property is adequately addressed (to implement minimum floor levels) and the problem is not worsened because of the development. Thus, if there is only a minor amount of flooding on a small part of the property it probably cannot be justified that the property should be subject to flood related development controls. All properties are inundated by overland flooding in a storm event and thus some "minimum" criteria must be adopted.

With the introduction of 2D hydraulic modelling and ALS a minimum depth or % inundation criterion has been adopted rather than a minimum flow criterion across the property (previously adopted by some Councils). The adopted depth criterion is generally in the range from 0.1m to 0.2m.

A suggested approach for residential developments (this can be applied to non – residential properties but other considerations are necessary) is as follows:

- All new houses must be built with their habitable floor and garage a minimum of 0.3m above the surrounding ground (the building code of Australia only requires 0.1m above

the ground for house floors). This assumes a maximum 0.15m water depth and a 0.15m freeboard (it is unrealistic to assume a 0.5m freeboard if the water depth is only 0.15m).
- A property is tagged if it is inundated by a depth greater than 0.15m and greater than 10% of the property is inundated by floodwaters (both conditions must be satisfied).

The above approach assumes tagging only to the 1% AEP extent and not to the 1% AEP +0.5m freeboard extent in overland areas. This approach is therefore inconsistent with the mainstream flooding approach. It might be considered acceptable as in overland flooding areas there is little difference between the 1% AEP and PMF levels (say less than 0.5m), thus tagging to the 1% AEP +0.5m freeboard extent might include properties not inundated in the PMF.

The major issue with the above is to provide definitions of mainstream and overland flow areas. This is not easy and is based on several factors. This is not a consideration for the Woolooware Bay catchment as there are no mainstream flooding areas (apart from Woolooware Bay).

RECOMMENDATIONS

The FPA developed from the Flood Study has been reviewed and has been updated as part of this study (Appendix B) to take account of ARR 2019 hydraulic modelling (Section 3.2) and the July 2021 flood planning updates.

8.4.7. Changes to Planning Policy

DESCRIPTION

Appropriate planning requirements which ensure that development is compatible with flood risk can significantly reduce flood damages. Planning instruments can be used as tools to:

- Guide new development away from high flood risk locations.
- Ensure that new development does not increase flood risk elsewhere.
- Develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population.

Examination of existing risk throughout the study area indicates that managing this risk is problematic due to the very short warning times available. Effective planning policy has the power to reduce this risk over time as the areas redevelop. Council should consider the long-term management of these areas and how this can be facilitated by planning tools. For example, high risk areas may need to be rezoned or have more stringent development controls applied to ensure areas of safe refuge onsite for shelter-in-place and flood compatible buildings.

DISCUSSION

Council should address development in flood risk areas in their DCP and provide matrices which apply varying degrees of restrictions to development based on the land use and flood risk. Applying stricter development controls in the hotspot areas has the potential to reduce the long-term flood risk.

GLN Planning were engaged to undertake a detailed review of planning in floodplain management, and this is provided in Appendix D. The following is a composite of the land use planning matters that were addressed by GLN Planning.

- Describe and examine the FRM process in NSW.
- The consistency of current or proposed future strategic planning directions for the community in relation to addressing floodplain management objectives.
- The adequacy of current land use planning and building controls for specific development areas or developments in relation to addressing floodplain management objectives and managing flood risk to both new development and limiting impacts upon the existing community.
- The suitability of different land uses in different areas of the floodplain considering their use and community response to flooding.
- The suitability of different land uses in different areas of the floodplain, considering the vulnerability of these uses and their users to flooding.
- The selection of appropriate flood planning levels, inconsistencies with the use of a singular FPL in the LEP and DCP, and related terminology used in the DCP.
- The DCP FRM provisions including the application of flood risk precinct in the DCP and consideration of the use of flood planning constraints categories approach, and the potential use of guidance notes to supplement the DCP.
- Opportunities for refining the use of restrictive covenants.
- The process for fence approvals that impact on flooding and consider potential voluntary fence modification schemes.
- The residual flood risk, following the instigation of general constraints and in relation to the need for additional constraints, where warranted, in specific areas of the floodplain.
- Analysis of both user and stakeholder needs.
- Provide recommendations for changes in land use planning directions or controls to address any identified shortcomings.
- Provide recommendations for planning instruments or alternate development controls to reduce the impacts of development on flooding and flood impacts on new development.

It is suggested that the current wording on the s10.7(2) certificate be reviewed and updated. This might include changing the word ‘restrict’ to ‘control’ as this provides a better description of the approach. Some Councils provide flood information together with the s10.7(2) certificate when it is purchased. An alternate and recommended approach is that the provision of flood information be kept separate from the s10.7(2) certificate given the technical challenges in integrating the two systems used to produce these documents.

RECOMMENDATIONS

A detailed review of planning in floodplain management undertaken by GLN Planning is provided in Appendix D together with their recommendations.

Revisions to planning policy should be considered when the planning instruments are updated in accordance with GLN Planning’s recommendations. Key elements include:

- Update to the development control matrix to include the type of development (e.g., change of use, alteration & addition, knock down & rebuild, etc) and the use or vulnerability of the development (e.g., recreation, typical residential development, sensitive or critical facilities, etc.).

- Incorporation of planning principles within the development objectives and controls to provide greater clarity on how to apply controls and meet objectives.
- Review and update to specific controls such that they are tailored to the type and use of the proposed development.
- Preparation of guidelines for assessing the impact of flooding on development and the impact of development on development.
- Providing guidance to development proponents on choosing the most appropriate development approval pathway i.e., complying development or DA.

8.5. Summary

A summary of the measures investigated, and outcomes are provided in Table 17.

Table 17: Summary of Specific Floodplain Risk Management Measures Investigated

MEASURE	PURPOSE	Outcomes
	FLOOD MODIFICATION	
LEVEES AND FILLING (Section 8.2.1)	Prevent or reduce the frequency of flooding of protected areas.	• Levees are suitable on large river systems where they can protect several buildings. • May cause local drainage problems and be unacceptable to the community due to restriction of waterfront access and views. • Levees will still be overtopped in major flood events and for this reason flood planning controls will still apply to areas protected by levees. • There are no suitable sites in the Woolooware Bay catchment.
TEMPORARY FLOOD BARRIERS (Section 8.2.2)	Prevent entry of floodwaters	• In a small catchment such as Woolooware Bay with a short warning time is unlikely to be practical for most buildings. • Possibly suitable for non-residential or suitable residential buildings.
CHANNEL CONSTRUCTION / FLOODWAYS (Section 8.2.3)	To channel floodwaters away from affected areas and so reduce flood levels.	• The creation of floodways can provide an effective means of diverting floodwaters away from affected areas and thus reducing flood levels. • There are no practical areas where a floodway could be created due to existing development.

CHANNEL MODIFICATIONS (Section 8.2.4)	To increase the capacity of the channel and so reduce flood levels upstream.	• The hydraulic capacity of the channel and floodplain can be increased by straightening of the channel, widening or removal of vegetation along the banks. • However, such measures can often increase flood risk downstream. • These measures are costly to undertake and generally require ongoing maintenance, have significant environmental impacts, are not an ecologically sustainable measure and are thus rarely used. • There are no practical areas where this measure could be undertaken due to existing development. • Council already conducts management of all creek systems.
REMOVAL OF HYDRAULIC RESTRICTIONS (Section 8.2.5)	To increase the capacity of the channel and so reduce flood levels upstream.	• The hydraulic capacity of the open channels and floodplain can be increased by removal of significant hydraulic restrictions such as narrow culverts or low-level bridges or even minimising the potential for blockage. • However, such measures can often increase flood risk downstream. • The larger measures (widen culverts or replace a bridge) are generally costly to undertake. Reducing the potential for blockage through regular maintenance is supported. • No location was identified which would provide a significant reduction in above floor inundation upstream.
DRAINAGE MAINTENANCE (Section 8.2.6)	Maintenance of the drainage network is important to ensure it is operating with maximum efficiency and to reduce the risk of blockage or failure and may involve removing unwanted vegetation and other debris.	• Is an ongoing issue for Council. • Has a large benefit in small frequent events but is of less benefit in large events that produce significant above floor inundation. • Requires further investigation to define the frequency and extent of the required maintenance works more closely.
FLOOD MITIGATION BASINS, RETARDING BASINS (Section 8.2.7)	Reduce the peak flow from the catchment by increasing the volume of temporary floodplain storage in the catchment.	• The size of storages required to make a difference need to be very large, making them impractical on environmental, social and economic grounds in the Woolooware Bay catchment.

ON-SITE DETENTION (Section 8.2.7)	Decrease effects of increased urbanisation.	• On-site detention or retarding basins are suitable measures to mitigate the potential increase in peak flow on downstream reaches. • There are no suitable sites for retarding basins. • Smaller on-site detention can help water quality and local drainage but has little impact along the main flow paths. • On-site detention is difficult to employ as a flood mitigation measure to reduce existing flood levels. • The existing OSD policy should be updated to meet current best practice standards and hydrologic / hydraulic modelling approaches.
PIPE UPGRADES (Section 8.2.8)	Pipe upgrades will reduce the overland flow and thus the peak flood levels.	• No parts of the network were identified as being of low capacity and could be upgraded relatively easily. • Upgrades by Council or developers should be undertaken when opportunities arise. • If pipe realignment is undertaken in private or public property, the developer should upgrade the pipe to a minimum 10% AEP capacity and preferably the 5% AEP capacity.
ASSESSMENT OF SEDIMENTATION AND BLOCKAGE (Section 8.2.9)	This measure was undertaken to provide advice on the effects of blockage of the culverts and channel entering Woolooware Bay.	• 50% blockage of the culverts and filling the channel to 0.5m AHD has only a minor impact on peak levels • In 100% blockage of the culverts and filling the channel to 1m AHD the impacts are much larger, affecting the two golf courses and in Taren Point adjacent to Woolooware Bay and on the west side of Captain Cook Drive opposite Endeavour Road.
FLOOD COMPATIBLE FENCING (Section 8.2.10)	The introduction of flood compatible fencing will reduce flood levels and create a continuous and relatively unrestricted flow path through private property	• Regulatory and voluntary flood compatible fencing is supported but the methodology of how it can be undertaken requires further investigation.
RESPONSE MODIFICATION		
FLOOD WARNING (Section 8.3.1)	Enable people to prepare and evacuate, to reduce damages to property and injury to persons.	• Relatively short warning time makes it impossible to provide a failsafe warning system. • Any system will provide some additional warning. • A sophisticated flood warning system is currently not viable for the Woolooware Bay catchment • It is important that this measure is still pursued as technological advancements may produce a system that will provide a benefit.

FLOOD EMERGENCY PLANNING (Section 8.3.2)	Effective planning for emergency response is a vital way of reducing risk to life and property.	• The cost to undertake this measure is small and will provide a high benefit/cost ratio. • The NSW SES and other emergency services should be relied upon for access during a flood rather than people venturing outside. • Shelter-in-place is recommended as the most viable means of protection in a flood for most of the catchment. SES endorsement is recommended. • Flood emergency plans are recommended for appropriate buildings.
COMMUNITY FLOOD EDUCATION (Section 8.3.3)	Educate people to raise awareness and prepare themselves and their properties for floods, to minimise flood damages and reduce risk to life. Strive for increased community resilience to floods.	• A cheap and effective method but requires continued effort. • Possible approaches are provided. • Can be linked to other water related issues such as water quality and sea level rise.
IMPROVED FLOOD ACCESS, ROAD CLOSURES AND NOTIFICATIONS (Section 8.3.4)	To ensure safe and reliable access during times of flood and to reduce the risk to life of vehicles entering flood waters.	• There is an existing problem and key locations were investigated. • Elimination of the flood hazard is not possible. • Flood depth indicators are recommended.
PROPERTY MODIFICATION		
HOUSE RAISING (Section 8.4.1)	Prevent flooding of existing buildings by raising the floor level above the floodwaters.	• All flood damages will not be prevented and only suitable for non-brick buildings on piers. • Costs approximately $80,000 per house but can vary considerably. • Only suitable for a small number of non-brick houses (generally with floor levels first inundated in the 10% AEP) or smaller events and not attractive to all residents. • No houses identified as suitable for raising.
VOLUNTARY PURCHASE OF INDIVIDUAL BUILDINGS (Section 8.4.2)	Purchase and removal of the most hazardous flood liable buildings to reduce risk to property and people.	• High cost per property. • Applicable for isolated, high hazard properties in flood liable areas. • No suitable houses were identified.
FLOOD PROOFING (Section 8.4.3)	Prevent flooding of existing buildings by sealing all the entry points. It can be either permanent or temporary.	• Generally, only suitable for brick, slab on ground buildings. • Less viable for residential buildings but should be considered for non-residential buildings of slab on ground construction. • The introduction of a Flood Resilient Housing Guideline specific to the Sutherland Shire LGA should be evaluated.

LAND USE ZONING (Section 8.4.4)	Reduce potential hazard and losses from flooding by appropriate land use planning.	• Potential changes in land use zoning that increase the density of population must consider whether these will significantly increase the risk to life, intangible damages, demands on the SES in flood times and other adverse consequences.
FLOOD PLANNING LEVELS (Section 8.4.5)	Provides a development control measure for managing future flood risk and for a house floor is derived from a combination of a flood event and a freeboard.	• The 1% AEP event plus 500mm freeboard for residential floors is appropriate for the Woolooware Bay catchment. Variations will only be considered where valid reasons are provided. • Minimum design levels for other land use activities should be adopted as part of a revised DCP.
FLOOD PLANNING AREA (Section 8.4.6)	It is important to define the boundaries of the FPA to ensure flood related planning controls are applied where necessary and not to those lots unaffected by flood risk.	• The FPA developed from the Flood Study has been reviewed and has been updated as part of this study (Appendix B) to take account of ARR 2019 hydraulic modelling (Section 3.2) and the July 2021 flood planning updates.
CHANGES TO PLANNING POLICY (Section 8.4.7)	Appropriate planning restrictions which ensure that development is compatible with flood risk can significantly reduce flood damages.	• A detailed review of planning in floodplain management undertaken by GLN Planning is provided in Appendix D. • Revisions to planning policy to provide stricter development controls in high-risk areas should be considered when the planning instruments are updated. • Wording on the s10.7(2) certificate should be reviewed and updated.

9. STRATEGIC FLOODPLAIN RISK MANAGEMENT

9.1. Overview

Strategic floodplain risk management is the understanding and consideration of the full range of flood behaviour and associated risks in prevention, preparation, response, and recovery activities to make the community as resilient as practicable to floods.

9.2. Flooding across Captain Cook Drive

Captain Cook Drive between Woolooware Road and Gannons Road is one of the most significant flooding hotspots in the catchment (Photo 11). Flooding is generally shallow in most events but can become hazardous at the location of the box culverts discharging to the mangrove lined channel adjacent to the new residential development, as well as adjacent to Dune Walk between Solander Playing Field and the new residential development.

Photo 11: Woolooware Golf Course / Captain Cook Drive / New Residential Development

Inundation of Captain Cook Drive currently (changes in road level in the past has affected the frequency of inundation) occurs on average every 2-3 years and results in closure of the road for several hours. Prior to development of the residential units on the west side of the Sharks football stadium this was not of significant concern as residents could avoid the area and alternate routes are available. With the construction of approximately 500 units their access is closed with no alternative access. A footpath across the rear of the football ground was proposed but as at 2022 this has not eventuated.

Runoff enters the road from several sources including Woolooware Road and Gannons Road but mainly from Woolooware golf course and the adjoining sports field south of the roadway. The only open channel exit to Woolooware Bay is via the mangrove lined channel on the immediate west of the football ground. Twin 2.7m by 1.2m culverts take runoff from the golf course under the roadway and exit into the open channel. Increasing the number or size of these culverts would decrease flood levels but not to any significant extent for the following reasons.

- A large proportion of the runoff resulting in inundation of Captain Cook Drive does not enter at the location of the culverts. Thus, flooding of the roadway would still occur regardless.
- Captain Cook Drive is a relatively wide (flooding occurs over a 500m length from Gannons Road to the football ground) and flat roadway. Thus, when it is overtopped a shallow across road depth (say 300mm) represents a significant waterway area and thus flow capacity. Realistically the culverts could only be doubled in size and this additional waterway area and capacity would be small compared to the quantity of flow across the road, thus only having minimal effect in reducing flood levels.
- Local runoff from rainfall falling on the roadway itself and not draining away rapidly causes flooding and this would not be affected by any additional culverts.

The main restriction preventing runoff from rapidly reaching Woolooware Bay is the relatively narrow mangrove lined open channel as the remainder of the overland area is blocked by raised ground, the new residential developments, or the existing football ground. Suggestions have been made to widen / dredge / clear the open channel. However, the reduction in peak levels would be relatively small involving significant loss of mangroves which cannot be justified.

The road is closed to pedestrian and vehicular traffic by emergency services at the onset of flooding. Durations of flooding vary but are around 3 hours. Traffic disruption is the most significant flood impact. There may also be damages to recreational facilities and utilities located on Woolooware golf course, Captain Cook playing field and Solander playing field and on the new developments, however damages have not been quantified.

There are no flood modification measures that will cost-effectively reduce flood depths and duration, and so reduce traffic disruption. Property modification measures such as wet and dry flood proofing should be considered for flood affected buildings in the vicinity. Flood emergency response is the main FRM measure recommended. Specific measures could include:

- Ensuring traffic diversion planning is undertaken and the outcomes included in the Georges River – Woronora River Local Flood Plan. Diversions should aim to direct traffic to the upper catchment via, for example, Cawarra Road, Port Hacking Road, Burraneer Bay Road, and Woolooware Road, and avoid high hazard areas on Gannons Road at the Kingsway and Denman Avenue intersections.
- Install flood depth markers.
- Engage with strata management from the new residential development to ensure the site flood emergency response plan is up to date and can be effectively implemented.
- Council maintenance crews should be on standby to safely remove network blockages where possible, and so minimise the duration of flooding.

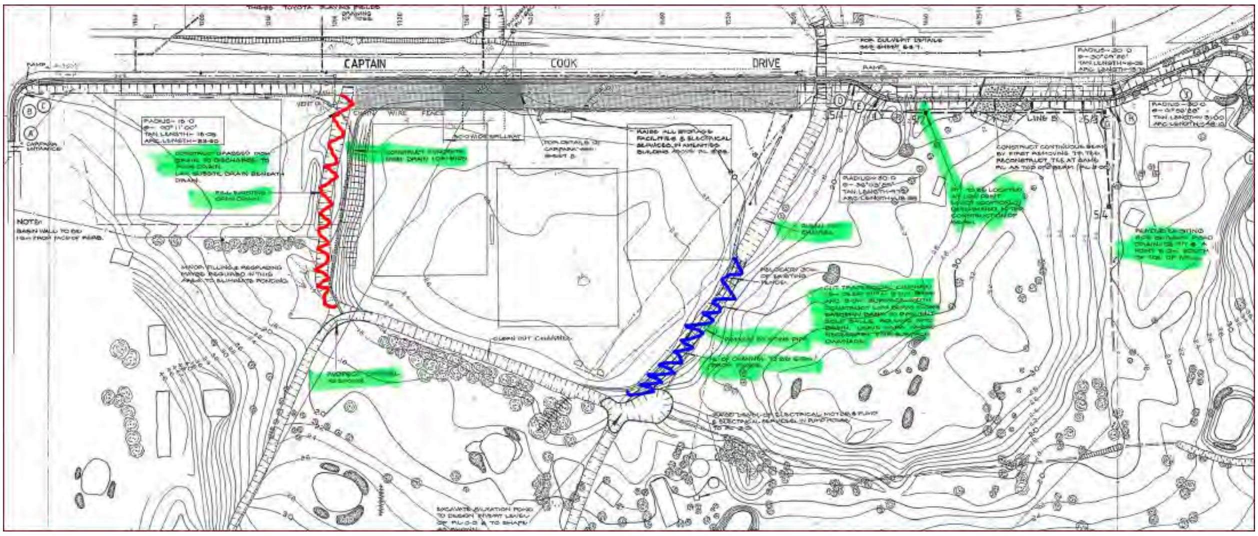
9.3. Woolooware and Cronulla Golf Courses

Cronulla GC was started in 1923 but only became an 18-hole course in 1957. Woolooware GC also originated as a 9-hole golf course and subsequently became an 18-hole course. The land used for both golf courses was low lying land ringed by mangrove swamps. Over the years extensive filling (part rubbish tip on Woolooware GC) has been undertaken to make the land playable and able to drain effectively. However, drainage is an ongoing problem for both courses. Woolooware GC tends to drain more quickly than Cronulla GC with the latter holding water for several days (refer Photo 4 and Photo 6).

There is no documented history of the stages of development of the two golf courses or on the playing fields to the east of the intersection of Gannons Road and Captain Cook Drive. Plans (refer Diagram 11) are available at Council showing proposed works in 1984 for the playing fields and partly within Woolooware Golf Course (holes 5 and 6). In summary these plans involved:

- <u>Works undertaken:</u> Filling in of the creek through the playing fields (shown in red) and removal of a pipe and creation of a new open channel (shown in blue) and upgrading of the culverts under Captain Cook Drive. Removal of open drains on northern side of Captain Cook Drive adjacent to the Solander playing fields.
- <u>Works either partially complete or not undertaken or unknown if undertaken:</u> Excavation and widening of the easement for the channel on the west side of the football ground, downstream of Captain Cook Drive. Formation of a raised embankment / cycle way on the southern side of Captain Cook Drive to 2.7 m AHD and creation of an outlet weir. Construction of dish drain in the playing fields. Excavation of a siltation pond and clearing out of the open channel on the northern boundary of the 5th hole on Woolooware GC.

Diagram 11: 1984 Plan of Works south of Captain Cook Drive within Solander playing fields and Woolooware GC



The works shown in Diagram 11 were referred to as the "Woolooware retention basin" and presumably were intended to reduce or control the inundation of Captain Cook Drive.

Whilst no golf is played during a flood and there is nil risk to life and minimal flood damages, the main issue is the ability of the golf courses to be returned to full use as soon as possible. Extensive works have been undertaken on Cronulla GC to address the problem and this included the $1.2 million installation of stormwater pipes in 1996. More recently fairways have been raised to improve drainage and a pump and gate system has been installed to pump out floodwaters.

At Woolooware GC the main issue is the poor drainage of the soil in the lower parts of the course (at Cronulla GC this has largely been addressed by raising the fairways). In places grass may die due to waterlogging and if this occurs in the winter months the grass cannot re-establish for several months. Compounding the problem is the ongoing use of the course with motorised buggies "churning up" the waterlogged ground. This issue has been addressed on the 8th and 12th fairways at Woolooware GC by the installation of car paths and low-level bridges in 2017. Filling has also been undertaken on Cronulla GC as identified by comparison of the 2007 and 2013 LiDAR (refer Appendix B).

In summary, there are no cost-effective drainage / floodplain management measures that could be employed at Cronulla GC to improve drainage as being a private club these have already been undertaken and paid for by member subscriptions and Council. At Woolooware GC (owned by Council) there are some suitable minor measures that could be introduced to improve the playability and thus the revenue from the golf course. These works are similar to those undertaken in 2017 and involve the regrading of fairways and installation of car paths to improve drainage and prevent damage to waterlogged ground. Anecdotal information and aerial photography clearly indicate that the small creeks on the 1st, 3rd and 5th fairways have widened over the last 20 years.

Whilst the past works on either golf course are very unlikely to have implications beyond the course it is important that management of both courses is undertaken in an environmentally sustainable manner. This would include:

- The creek systems (particularly in Woolooware GC) must not be cleared of vegetation (Photo 12) for the purpose of benefiting golfers retrieving golf balls or perceived flood mitigation benefit. The vegetation acts as a bank stabiliser limiting erosion and providing habitat. Any major vegetation clearing must be supported by Council's environmental officer.

Photo 12: Channel from under Woolooware Road into golf course cleared of vegetation

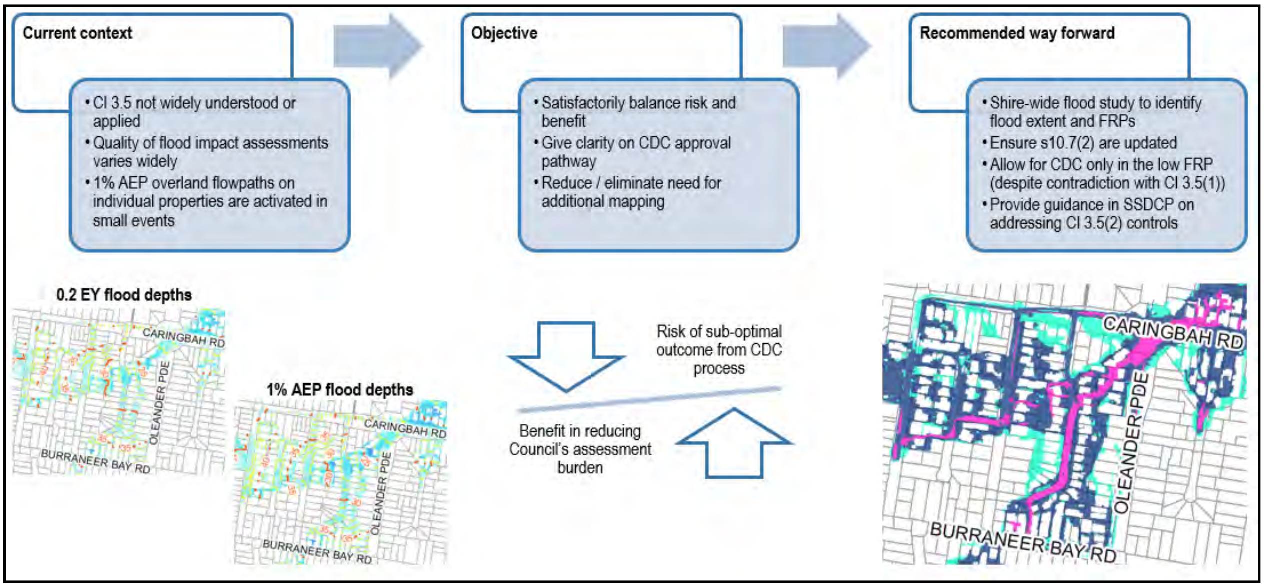
- The banks of all creeks (particularly in Woolooware GC) must be allowed to stabilise, and a vegetation management plan undertaken and implemented.
- Whilst erosion of the banks has occurred and is not acceptable the creeks do not appear to contribute a significant amount of sediment to downstream properties.
- All significant works particularly filling must be undertaken via a DA to Council.
- Any filling or landscaping works on the golf course should consider potential flood impacts on neighbouring upstream properties, particularly at No 97 – 105 Denman Avenue and at the northern ends of Harnleigh Avenue, Dolans Road and Arcadia Avenue.
- Both golf clubs should voluntarily consider developing a flood emergency response plan, particularly for Woolooware GC where the club building is set low and egress from the club to Gannons Road is through high hazard floodwaters.
- Under its lease agreement with Woolooware GC, Council is responsible for maintaining the channels crossing the golf course. Maintenance is mostly undertaken by Council reactively in response to sedimentation and weed infestation.

These management practices may assist in improving local drainage but will have little benefit in reducing flood levels across Woolooware GC in more than the most minor floods. Future management should be aimed at improving the ecological integrity of the channels. This should be addressed collaboratively with the club and ideally as part of a broader catchment planning approach for the Woolooware Bay catchment that considers inter-related issues of water quality, sediment, biodiversity, and amenity. A more specific masterplan or management plan may be warranted for the channels that outlines the different objectives for the channels, a long-term strategy, agreed service levels, etc.

9.4. Development Approval Pathways for Flood Control Lots

If a development is not properly controlled leading to on-site or off-site impacts, Council could see an increase in complaints, most likely in minor storms because of their high frequency. The pathways for development approval on a flood control lot are either as a Complying Development or through the Development Approval process. Council prepared a diagram (Diagram 12) outlining the issues in the two approaches.

Diagram 12: Approval Pathways on Flood Control Lots



Council considers that the problem is that the Code SEPP applies controls to areas outside the high risk, high hazard, floodway / flood storage areas, which are generally narrow in the upper catchment. A developer / certifier / consulting engineer could simply look at the flood hazard or hydraulic categorisation maps and determine that a complying development is suitable (albeit they still need to comply with Code SEPP controls which may involve flood modelling). Council has no control over this and considers that it might receive complaints if the complying development does not fully meet the Code SEPP controls. Anecdotal information indicates that some consulting engineers will not undertake a complying development assessment for a flood control lot as the criteria are too ambiguous.

Council wishes to simplify the approval process, reduce the ambiguity, provide greater certainty, and reduce the workload for Council and the consultant by providing clearer direction to the developer. One solution is to simply define the 1% AEP flood extent as the 'flow path' listed in the Code SEPP controls for the purposes of determining the approval pathway. This would mean that complying approvals would not be permitted on land within the 1% AEP extent. This and other possible approaches should be reviewed as part of the review of Council's planning approaches in floodplain management.

9.5. Guideline for Flood Impact Assessments

A critical component of a DA for works on flood liable land is provision of a flood impact assessment (FIA). Accurate assessment of the FIA is essential to ensure that the proposed works comply with the relevant planning controls in the DA and that flooding is not exacerbated outside the subject property as detailed in the LEP. The main objectives of the assessment are to:

- ensure safety of all residents, visitors, and emergency response personnel,
- minimise damages in a future flood,
- negate any adverse affectation greater than 10mm in the 1% AEP event outside the subject property,
- optimise the development potential of the site taking into consideration climate change but ensuring minimal social and environment harm and complying with best practice in floodplain management.

A clearly understood guideline will minimise effort by the developer's consultant in determining the approach to be taken and the required outputs. It will also ensure that Council Officers can more rapidly determine the DA. Key features that need to be included in the guideline are:

- Criteria for determining the nature and extent of the FIA as not all works will require a rigorous hydraulic modelling approach.
- Availability of existing flood information, reports and modelling.
- Qualifications and experience of the practitioner submitting a FIA.
- Information to be supplied in a FIA.
- Information on acceptable modelling approaches and the use and availability of Council's existing flood models.
- Clear description of the outputs and flood events that are required in a FIA and the objectives that must be achieved.
- Suggestions to improve the quality of FIAs.

9.6. Approval to Re-Align Pipes as part of a Development Application

For properties with a drainage easement and a pipeline beneath there is a tendency for developers to ask to re-align the pipe to provide more useable space for their development. Generally, this is supported but the following guidelines are suggested:

- The pipe should be upgraded to a 5% AEP capacity.
- Hydraulic modelling must be undertaken to ensure that there are nil adverse impacts (i.e., the capacity of the existing pipe is maintained or increased for all design events). This would require adequate representation of pipe bend losses.
- Pipe realignment will generally require lengthening the pipe length which will therefore reduce the pipe grade and thus potentially have implications for sedimentation which should be assessed.

Pipe realignment during redevelopment should be encouraged where it is coupled with pipe upsizing and provision of additional upstream inlet capacity, to increase conveyance capacity. However, depending on its location in the catchment, this will likely be of benefit in reducing overland flows only in relatively small storm events.

9.7. Approval for Buildings on Piers

Construction of buildings (particularly houses) on piers has become a relatively common approach in the last 10 years to ensure that a new building, with a larger footprint than the existing structure, can be approved without impacting on flood conveyance or loss of temporary floodplain storage. In many locations this approach is acceptable. Flow under buildings can sometimes cause issues such as excessive dampness, odours, sediment, and debris accumulation, etc. This can be of consternation to property owner and contribute to intangible damages. The significance of these issues is related to how frequently these issues occur.

Infilling of the below floor area is an access issue that can be addressed by preventing access with flood compatible fencing. However, in time residents may circumvent the fencing and build walls or similar. A positive covenant (as used for OSD) or stipulating a drainage easement on the title could be adopted to prevent this occurring but this may be considered too rigorous. At a minimum Council should maintain a database of these raised properties if a review of the present approach is required in the future.

The other significant potential issue with piered construction is the possibility that future landowners will experience frequent below floor inundation and complain to Council of dampness or loss of amenity. To date this is not known to be a problem as the last 15+ years has been a relatively dry period.

This issue was investigated through an analysis of the last 120 years of daily rainfall at Observatory Hill (longest record in NSW). It was assumed that 80mm of rainfall in a day (ignoring rainfall covering consecutive days) might produce overland flooding and this provided the following results:

- 88 years had a daily total above 80mm.
- 45 years had two daily totals above 80mm.
- 21 years had three daily totals above 80mm.
- 8 years had four daily totals above 80mm.
- 1 year had five daily totals above 80mm.

Based upon the above results it is unlikely that the frequency of inundation will be a significant problem for overland flow areas, however adjacent to rivers, creeks, or other forms of open channels it may be an issue. Council should therefore monitor its future flood complaints records and link this to the database of piered buildings. A possible condition is to only allow piered construction if on land above a minimum level, such as the 20% AEP event.

For redevelopment involving knock-down and rebuild and no intensification (specifically no increase in the number of people or families), flow beneath buildings should not be an issue. Satisfying the flood effects clause by allowing flows through the sub-floor space is prioritised over addressing amenity issues. For redevelopment involving intensification (e.g., secondary dwelling, replacement of single dwelling with higher density development, etc.), more consideration should be given to the amenity impacts of allowing flow beneath new buildings.

Where practicable, new buildings should be sited in areas of least flood affectation to avoid the risk (primarily frequency) of amenity impacts associated with flows through the sub-floor. Further guidance on this should be outlined in the flood impact assessment guidelines to be prepared in support of DCP Chapter 40.

9.8. Cumulative Flood Impacts

Cumulative impacts relate to the gradual increase in flood risk arising from multiple small decisions or actions taken regularly over time. There are several aspects to cumulative impacts.

- One aspect relates to stormwater management in the private and public domain. Stormwater runoff can increase over time due to not only an increase in impervious areas but their direct connection to the existing drainage systems (i.e., effective impervious areas (EIA)).
- EIA in the private domain is usually managed by OSD however the effectiveness of Council's current OSD policy, as well as ongoing compliance, is highly uncertain and likely to be poor. EIA that is classified as exempt or complying development (e.g., pergolas, patios, paved areas, etc) is unlikely to be controlled at all. Increased EIA in the public domain because of improved kerb and guttering, footpath construction / widening, new drainage, etc, is also uncontrolled.
- The impact of a single uncontrolled increase in EIA is greatest locally and in small storms. Hydrologic modelling undertaken for the nearby Ewey Creek catchment suggests, however, the cumulative impact of an uncontrolled increase in EIA because of predicted residential development over the next 20 years will not significantly increase catchment design storm flows.
- Notwithstanding, Council should continue to aim to avoid any increase in stormwater runoff and resultant flood risk and, where practicable, seek to reduce runoff in line with a 'yield-minimum' catchment strategy.
- A second aspect to cumulative impact relates to the offsite impacts of redevelopment. Although not codified in the DCP, Council only allows a 10 mm increase in offsite flood levels usually up to the 1% AEP event. This issue is discussed further below.
- A third aspect relates to certain types of redevelopments. For instance, the cumulative impact of re-development where the existing building is retained and where existing floor levels are less than design floor levels, can only be managed through the application of other development controls such as building components clause. This clause is not nearly as effective as having raised floor levels and may result in a gradual increase in flood risk as properties are redeveloped. Redevelopment can also result in additional people being added to the floodplain. While controls should ensure no cumulative increase in tangible direct and indirect damages there may be an increase in intangible damages. Without shelter-in-place, additional residents in the floodplain can lead to cumulative impact on flood emergency response e.g., increased traffic issues during flooding.

FRMS&Ps and FIAs for developments in the floodplain are generally required to address the implications of cumulative flood impacts. This issue originally arose before detailed flood modelling was available. Thus prior to 1980 little (if any) consideration was given to the flood impacts of developments on the floodplain and thus cumulative flood impacts were assumed to represent the future total of these impacts. With the advent of sophisticated computer modelling and notably since approximately the year 2000, most private and public works on the floodplain are assessed prior to development approval. This occurs either as part of an environmental impact statement or a FIA required for development approval by a Council.

Sutherland Shire Council's LEP and DCP requires these assessments to be undertaken and to demonstrate that there are minimal adverse flood impacts on surrounding properties (though generally only in events up to the 1% AEP). Thus, no future development should occur on the floodplain which will have adverse impacts and thus contribute to cumulative flood impacts.

Each future development may have minor impacts (say +10mm outside their property) however the cumulative effects of these are too small to be of relevance.

A FIA is generally assumed to consider only the increase in peak flood level on adjoining properties. Consideration should be given to the potential cumulative increase in intangible damages (inconvenience, involvement of the SES) as well as increase runoff in minor rainfall events due to a greater EIA.

9.9. Collection and Management of Flood Data

A critical component of best practice floodplain risk management is the collection and use of flood data. For major river systems this is undertaken by state or federal government agencies such as the BoM, Sydney Water, Hunter Water and the DPIE. For smaller catchments such as Woolooware Bay which has no river or creek running through the catchment Council must take on this role. Floods provide the only opportunity to analyse how successful the flood mitigation measures are in reducing flood damages, reducing the risk to life and to verify the design flood estimation procedures. It is essential therefore that all available flood data is collected from any future flood.

Rainfall data from the BoM has always been readily available but over the last 20+ years many pluviometers (automatically record rainfall as it is falling) have been installed by local authorities or sporting clubs. After every flood Council must collect all available daily read and pluviometer data within 10 kilometres of the catchment. This should be done immediately following the event.

The collection of flood data is more difficult and will generally require some form of questionnaire and article in the local paper or on Council's web site to discover what data is available. Residents may also contact Council as they were affected by the flood (blocked kerb inlet, water caused their fence to fail). This data might include:

- Peak flood levels from debris or other marks.
- Photographs and subsequent survey of peak levels.
- Recollections from people who experienced the flood such as rates of rise, peak depth, velocity etc.
- Flood damages data from residents or insurance companies (if available).

Following collection of the data it is important that it is written up in a report and placed in Council's records. Depending upon the nature and extent of the data, consideration should be given to comparing the peak levels, rainfall intensities etc. to those adopted in this FRMS&P. If the recorded data suggests that the FRMS&P results are in doubt a full review of the modelling approach should be undertaken. As a guide an event that has rainfall intensities greater than a 10% AEP should be re-modelled with the model results compared to the recorded data.

Council's management of the flood data should also be improved to account for:

- Identifying needs of users of flood data.
- Understanding life cycle of flood data.
- Identifying measures for improving the system for the generation, storage, display and reporting of flood data.

An indicative cost to develop a flood data program is $100,000.

9.10. Flood Insurance

Flood insurance does not reduce flood damages but transforms the random sequence of losses into a regular series of payments.

It is only in the last ten years or so that flood insurance has become readily available for houses, although it was always available for some very large commercial and industrial properties. There are many issues with the premium for this type of insurance as well as how insurance companies evaluate the risk (for example an insurance company may base premiums on ground level or may choose to consider the actual floor level of the development). These issues are outside the scope of this present study and were assessed as part of the Commission of Inquiry into the South East Queensland floods of January 2011. Flood insurance at an individual property level is encouraged for affected landowners but is not an appropriate risk management measure as it does not reduce flood damages.

Flood insurance is a private risk management matter for flood-affected property owners that is usually beyond the scope of FRMS&Ps. However, FRM measures recommended in FRMS&Ps would, when implemented, aim to reduce flood damages and, over time, the number and value of insurance claims. The success of these measures could potentially be measured over time in terms of actual flood damages sustained and claimed for. This would be challenging, however, given that two flood events are very rarely the same (making it difficult to compare damages), the time between significant events, and commercial and privacy issues associated with sharing flood damage data. An alternative is to conduct targeted surveys (flood level survey, damage assessment, etc) in the aftermath of flood events to give a partial or representative indication of the effectiveness of FRM measures.

The insurance industry relies on digital flood data, often generated through the FRM process, to accurately price insurance policies. Council should consider the merits of making available the data from this project to the insurance industry.

Flood affected property owners frequently raise flood insurance as a key issue. Council should continue to direct queries to the Insurance Council of Australia in the first instance.

Continued access to flood insurance in flood-affected areas is, in part, dependent on the current system of flood studies and risk management planning represented by this FRMS&P. This planning must include consideration of the future risk from sea level rise and climate change.

Council should assist the Insurance Council of Australia where applicable.

9.11. Integration with Council's Asset, Catchment and Waterway Management

Sutherland Shire Council is applying an asset management approach to its stormwater and waterway assets in line with the Integrated Planning and Reporting framework. Council's Stormwater & Waterways Asset Management Plan has been extensively updated, with minor flood protection, major flood protection and flood emergency response added as important community objectives. Council's inventory of stormwater and waterway assets is also being updated and will form the basis for undertaking and reviewing overland flood studies to assess asset performance and to inform management response.

The interaction between FRM and traditional stormwater and waterway management is often blurred in overland flow situations. The FRMS&P is attempting to better define these management approaches as well as the extent of their interaction, as part of the development of the Catchment & Waterway Management Strategy. Common elements for consideration include on-site detention and retention, use of flood models for investigation and design of stormwater drainage upgrades and stormwater quality improvement devices, and the impacts of sedimentation and riparian vegetation on flood flow conveyance.

9.12. Summary

A summary of the strategic measures investigated, and outcomes are provided in Table 18.

Table 18: Summary of Strategic Floodplain Risk Management Measures Investigated

MEASURE	PURPOSE	OUTCOMES
STRATEGIC MANAGEMENT MEASURES		
FLOODING ACROSS CAPTAIN COOK DRIVE (Section 9.2)	Inundation of Captain Cook Drive occurs on average every 2-3 years causing travel delays.	• Captain Cook Drive is a major throughfare and flooding causes significant traffic disruption. • There are no flood modification measures that will cost-effectively reduce flood depths and duration, and so reduce traffic disruption. • Flood depth indicators and flood awareness will assist in managing the problem.
WOOLOOWARE AND CRONULLA GOLF COURSES (Section 9.3)	The two golf courses cover a large part of the lower floodplain and their management must be addressed.	• The main issue is poor drainage resulting in loss of revenue until golfers can return. • Minor measures on Woolooware golf course are viable. • Cronulla golf course is a private club and has already undertaken management measures. • Measures should be taken to improve the environmental sustainability of both courses.
APPROVAL PATH FOR FLOOD	If development is not properly controlled this	• Council wishes to simplify the approval process. • Possible approaches should be reviewed as part

CONTROL LOTS (Section 9.4)	may lead to on-site or off-site impacts	of the review of Council's planning documents.
GUIDELINE FOR FLOOD IMPACT ASSESSMENTS (Section 9.5)	To ensure that there are clearly understood guidelines for undertaking a flood impact assessment.	• The guideline will minimize effort by both the developer's consultant and Council Officers. • Will ensure that high quality and consistent FIAs are submitted.
APPROVAL TO RE-ALIGN PIPES AS PART OF A DA (Section 9.6)	Re-alignment of pipes as part of a DA provides an excellent opportunity to upgrade the pipe capacity	• This is a cost effective means of pipe upgrading. • A suggested upgrade capacity is the 5% AEP.
APPROVAL FOR BUILDING ON PIERS (Section 9.7)	Potentially this approach may introduce adverse amenity issues.	• Building on piers is a means of ensuring nil increases in flood level with a larger footprint. • This approach is supported but needs to ensure that it does not introduce adverse amenity issues.
CUMULATIVE FLOOD IMPACTS (Section 9.8)	Small increases from single developments may result in a large cumulative increase.	• A rigorous flood impact assessment should eliminate significant cumulative increases in flood levels. • Potentially there may be a cumulative increase in intangible damages (inconvenience, SES involvement).
COLLECTION AND MANAGEMENT OF FLOOD DATA (Section 9.9)	Provide consistent approach to managing flood data	• Essential to collect all available flood data after each flood. • If applicable the collected data should be compared to the design results. • Management of the flood data should be improved.
FLOOD INSURANCE (Section 9.10)	To spread the risk of individual financial loss across the whole community through insuring against flood damage.	• Does not reduce damage but spreads the cost. • These issues are outside the scope of this present study. • Flood insurance at an individual property level is encouraged for affected landowners but is not an appropriate risk management measure as it does not reduce flood damages. • Insurance against storm surge, tidal inundation, and permanent inundation from sea level rise is not generally available. • Council should assist the Insurance Council of Australia where applicable.

INTEGRATION WITH STORMWATER ASSET, CATCHMENT & WATERWAY MANAGEMENT (Section 9.11)	To optimise management of the catchment and waterway consistent with Council's Community Strategic Plan, Delivery Program and Operational Plan	• The interaction between FRM and traditional stormwater and waterway management is often blurred in overland flow situations. • There are means to improve this interaction. • Common elements for consideration include on-site detention / retention and use of flood models for investigation / design of stormwater drainage upgrades, and analysis of sedimentation and vegetation impacts.

10. FLOODPLAIN RISK MANAGEMENT PLAN

10.1. Introduction

The Woolooware Bay Floodplain Risk Management Plan has been prepared for Sutherland Shire Council in accordance with the NSW Government's *Floodplain Development Manual* 2005 (Reference 2) and:

- *Is based on a comprehensive and detailed evaluation of factors that affect and are affected by the use of flood prone land.*
- *Represents the considered opinion of the local community, Council Officers and the Sutherland Floodplain Management Committee on how to best manage its flood risk and its flood prone land.*
- *Provides a long-term path for the future development of flood prone lands.*

There are several important elements that were considered in putting together the plan:

- Options for property modification, behaviour modification and strategic floodplain risk management are mutually supportive and should ideally be pursued concurrently.
- Many of the actions are for feasibility investigations and designs of projects / programs. This will determine the scope and cost of the project / program. Programs should be implemented under the auspices of Council's forthcoming Catchment and Waterway Strategy and Implementation Plan. Council should investigate funding mechanisms for actions that potentially sit outside the FRMS&P process.
- Investigation of the proposed voluntary schemes need to consider each other as well as the rates of redevelopment. The offer of financial or development incentives should be inversely proportional to the probability of redevelopment.
- Prioritisation of action is shown as timeframe to start and timeframe to finish. Prioritisation was based on Council's considered capacity to deliver the actions, the likelihood of grant funding assistance and effectiveness in reducing flood risk.
- The recommended actions can only progress within the resourcing and funding constraints of Council and the NSW Government. Notwithstanding, Council should consider opportunities to undertake this work using in-house resources with specialist external input and review as required. This will promote ownership of the work by Council staff and improve internal capacity to undertake similar work in the future.

10.2. Recommended Measures in the Woolooware Bay Floodplain Risk Management Plan

Table 19: Recommended Measures in the Woolooware Bay Floodplain Risk Management Plan

Measure	Purpose	Recommended Actions	Indicative Costs	Projected Start	Projected Finish
Strategic Floodplain Risk Management Measures					
Flood data collection and management	Provide consistent approach to managing flood data	Improve system to manage flood information • Identifying needs of users of flood data • Understanding life cycle of flood data • Identifying measures for improving the system for the generation, storage, display and reporting of flood data	$100,000	Immediate	Medium
On Site Detention	Decrease effects of increased urbanisation.	The application of OSD should be continued and linked to stormwater flooding. However, OSD is more complex than originally envisaged and updating the OSD philosophy and the SSR and PSD requirements must be undertaken using current best practice modelling. Feasibility investigation to assess the impact of OSD on flooding.	$100,000	Immediate	Short
Integration with Stormwater Asset, Catchment & Waterway Management	To optimise management of the catchment & waterways consistent with Council's Community Strategic Plan, Delivery Program and Operational Plan	• Consider opportunities for integrating flood model results into Council's corporate asset management • Consider using flood model for stormwater drainage investigation designs • Using the flood model to consider the flood implications for waterway management & stormwater quality improvement	Internal cost	Short	Medium
Behaviour Modification Measures					
Improve flood access, road closures and notifications	To ensure safe and reliable access during times of flood and to reduce the risk to life of vehicles entering flood waters.	Flood depth indicators at road crossings are an appropriate cost-effective measure to advice drivers of the depth of flood waters. It is recommended to install flood depth markers as discussed with SES on Captain Cook Drive, Gannons Road-Denman Avenue and Endeavour Road	$20,000	Short	Short

Flood warning	Enable people to prepare and evacuate, to reduce damages to property and injury to persons.	Investigate feasibility of designing the desirable flood warning system utilising pluviometer data from Sydney Water and others in the Woolooware Bay catchment.	$60,000	Short	Short
Community flood education awareness and resilience	Educate people to raise awareness and prepare themselves and their properties for floods, to minimise flood damages and reduce risk to life. Strive for increased community resilience to floods.	Develop community education and awareness program, in consultation with the NSW SES, considering the following methods of engagement: • Establish clear goals and objectives • Flood information brochures (mail outs, letterbox drop) • Inclusion of educational materials with rates notices in the mail • Targeted consultation with the vulnerable community and owners and occupiers of property in the floodplain • Flood information booths with SES volunteers • Advice on temporary flood barriers / protection • Community engagement • Increased community resilience to floods	$70,000	Short	Medium
Property Modification Measures					
Flood controls & flood impact assessment guidelines	Update flood related development controls in Sutherland Shire DCP 2015.	• Review proposed changes to Sutherland Shire Council DCP Chapter 40 Part C – Flood Risk Management • Provide guidance on approval pathway • Update development control matrix • Provide flood impact assessment guidelines • Update the DCP to incorporate regulatory flood compatible fencing • Provide advice on flood emergency planning • Consider Shelter-in-place where practicable and in consultation with NSW SES • Consider updating DCP Chapter 38 – Stormwater and Groundwater Management as recommended by consultant's GLN Planning • Review and update Council's 2009 Stormwater Specifications • Consult with Council's strategic planners to determine best approach for updating the DCP	Internal cost	Immediate	Short

		• Follow appropriate Council procedures to implement changes to the DCP • Amendments to be in accordance with the NSW Flood Prone Lands Package • Communicate revised development controls to residents and relevant stakeholders • Develop an approach to apply development controls on a catchment-by-catchment basis, considering variable freeboard			
Voluntary redevelopment	Minimise flood risk by promoting redevelopment in accordance with Council's DCP.	Incentivised early redevelopment to minimise flood risk would require extensive investigation to determine its viability in the Woolooware Bay catchment. It is recommended to investigate feasibility of promoting redevelopment of flood affected buildings in the Woolooware Bay catchment. Incentivised redevelopment is not considered eligible for grant funding under the NSW Floodplain Management Program.	$60,000	Medium	Medium
Voluntary flood proofing	Prevent flooding of existing buildings by sealing all the entry points. It can be either permanent or temporary.	Voluntary flood proofing can be applied as a retrofit measure for an existing flood liable building to provide additional protection. Investigate the feasibility of designing and developing a program to raise flood awareness, provide practical advice on flood proofing measures and financial assistance to implement these measures.	$60,000	Medium	Medium
Voluntary fence modification	To reduce flood levels and create a continuous and relatively unrestricted flow path through private property.	Investigate the feasibility and compliance issues of designing and developing a program to promote voluntary fence modifications.	$70,000	Medium	Medium

Timeframes have been classified as immediate (2022/23), short term (1 to 2 years) and medium term (3 to 8 years) and have been allocated based on consideration of available resources, competing priorities, and predicted funding. Costs will be updated based on more detailed scoping, available funding and market responses.

10.3. Monitoring, Evaluation and Review

It is essential that the program of works is monitored on an annual basis with the success of each measure evaluated with reporting to the floodplain management committee. A more comprehensive review is required at 5-year intervals, but more frequently if there is a significant change with any of the proposed works, after the next major flood or after a significant technological advance or update to FRM or modelling guidelines

Council will have to be prepared to face community queries on its actions and implementation of the outcomes of this FRMS&P following a significant flood event.

There is a need to stress the different approaches between stormwater management and floodplain risk management. Stormwater management is concerned with the operation of the stormwater pit and pipe network that only address very minor events. The state of the network in terms of maintenance or hydraulic capacity does not influence major flood behaviour.

It is important to acknowledge that reduction in flood risk as a term long term endeavour relies almost solely on property modification measures and behaviour modification measures. This message will need to be regularly conveyed to the community and other stakeholders both during and after floods.

11. ACKNOWLEDGEMENTS

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Sutherland Shire Council has prepared this document with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the DPIE.

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Figures

FIGURE 1
WOOLOOWARE BAY CATCHMENT STUDY AREA

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FIGURE 2
WOOLOOWARE BAY CATCHMENT LAND USE MAP

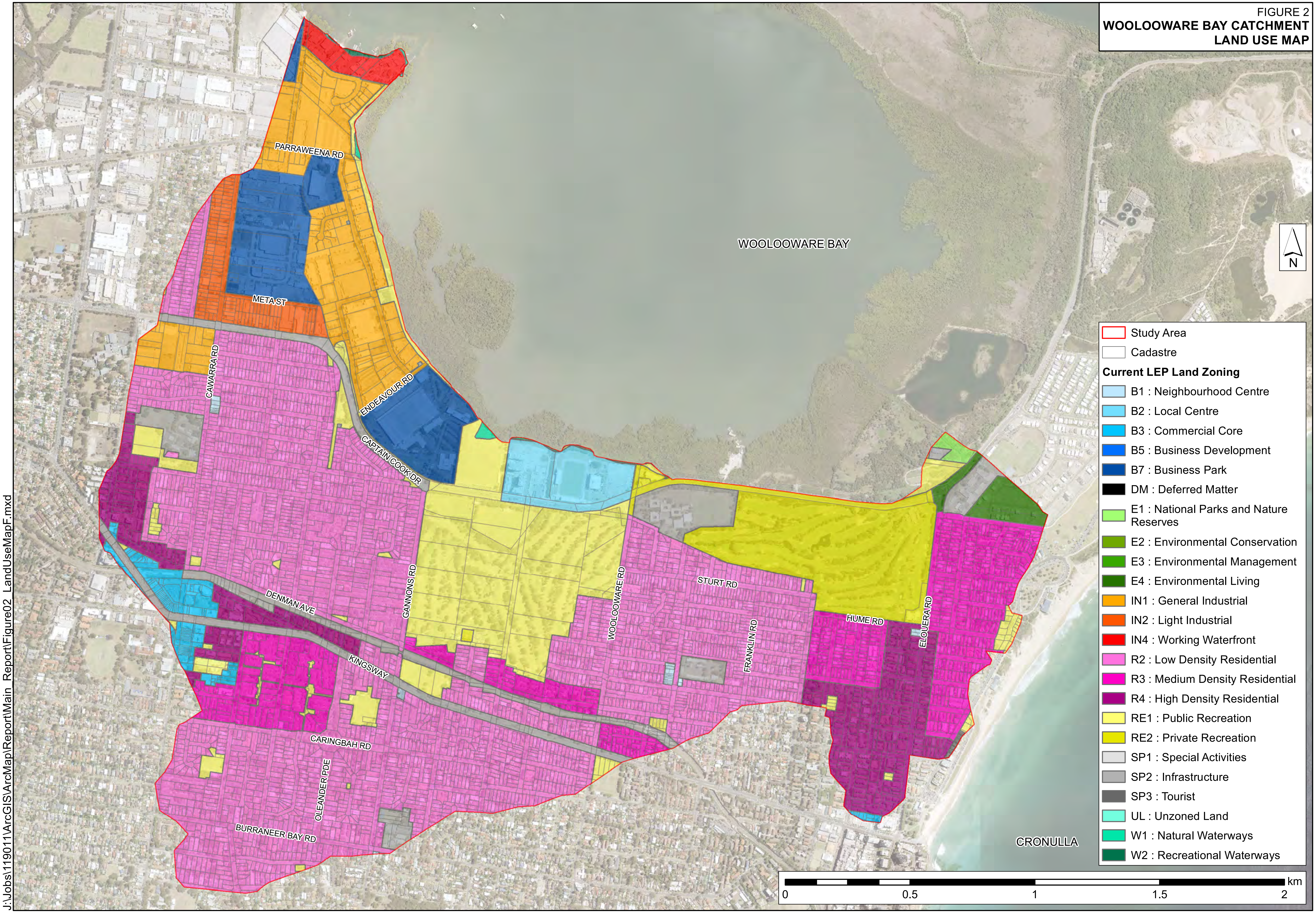

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FIGURE 3
WOOLOOWARE BAY CATCHMENT FLOOR LEVEL DATABASE

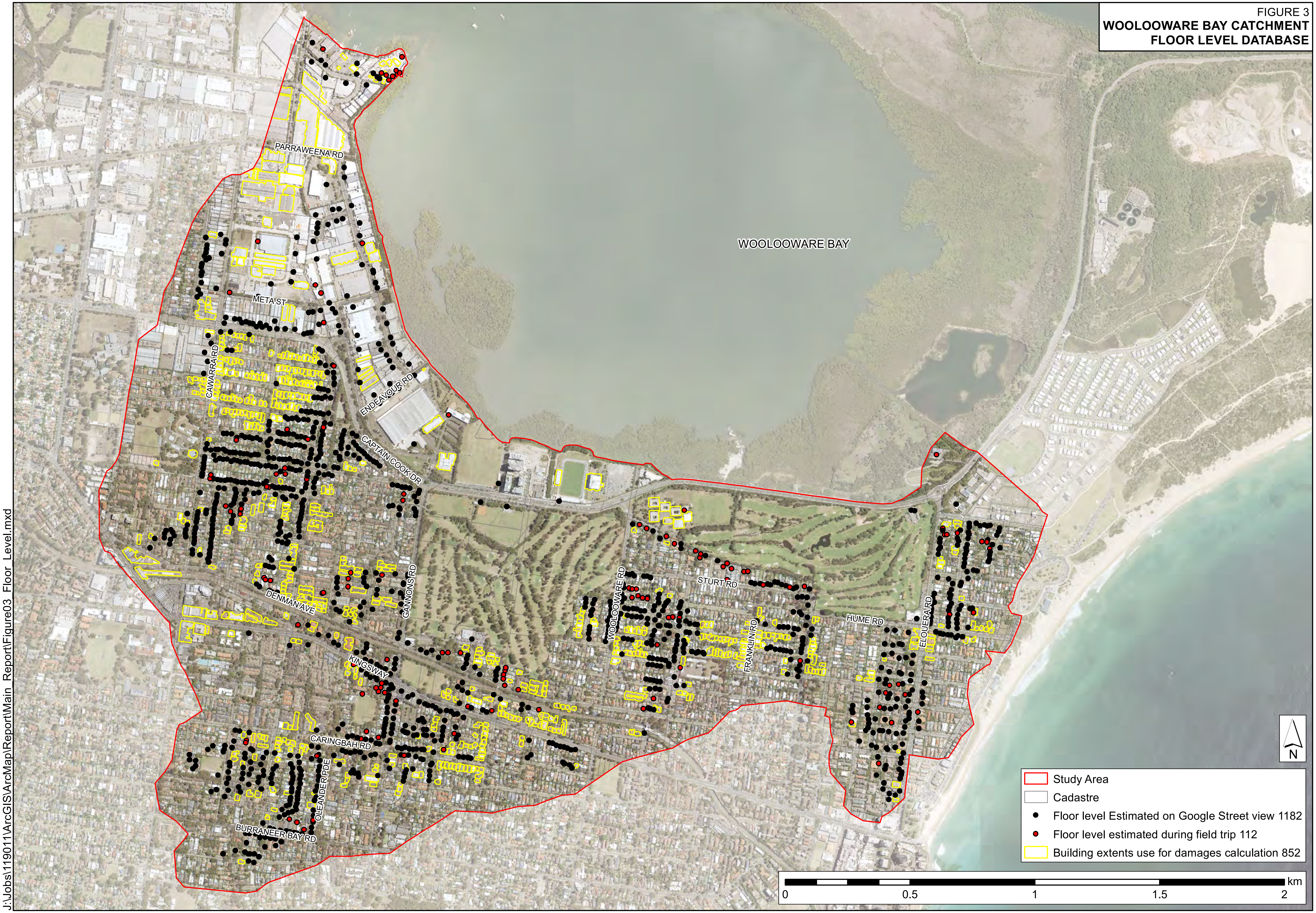

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FIGURE 4
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
REVISED MODEL ARR2019 V 2014 FLOOD STUDY ARR1987
1% AEP EVENT

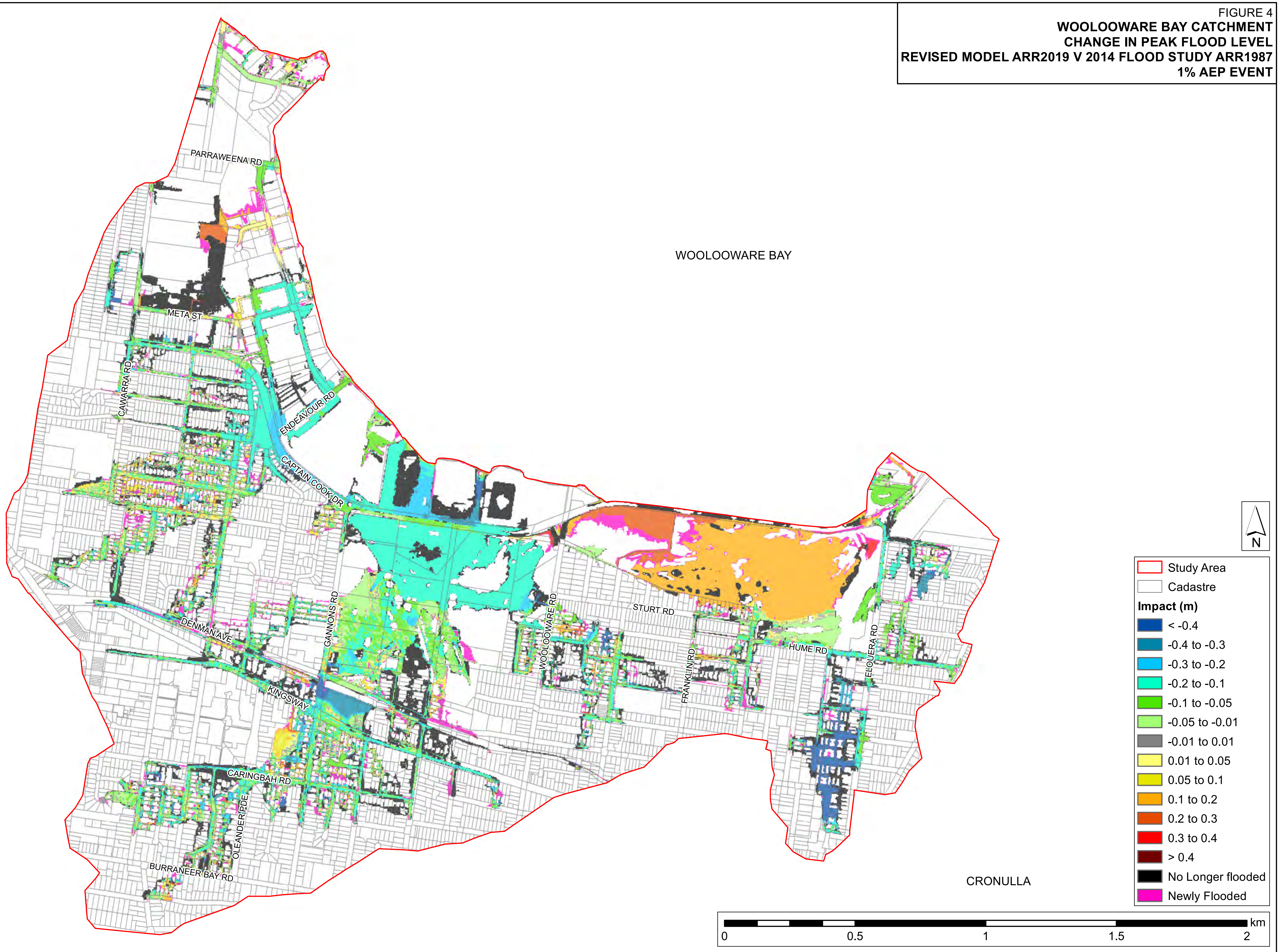

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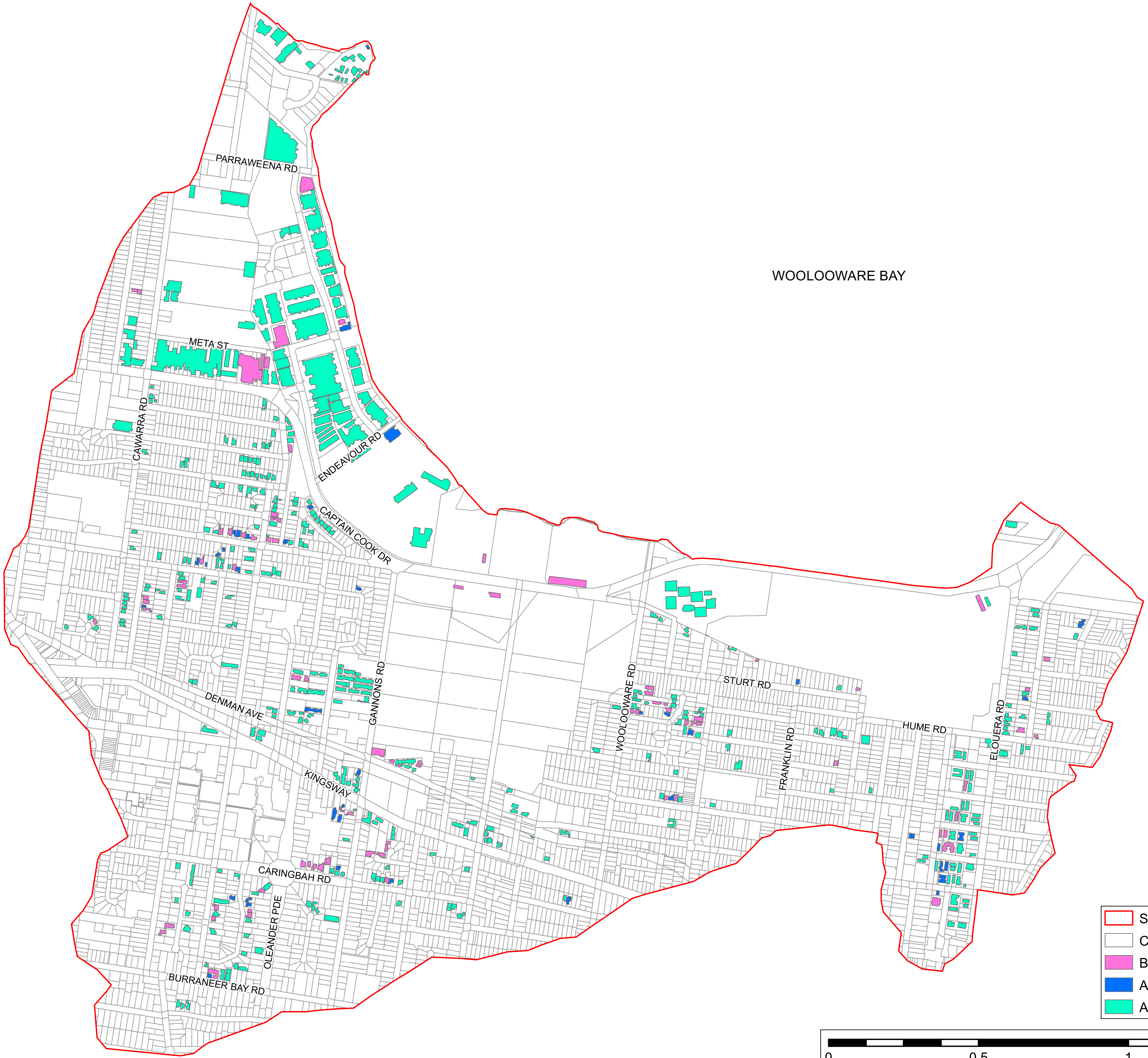
FIGURE 5
WOOLOOWARE BAY CATCHMENT
BUILDING FLOORS FIRST INUNDATED



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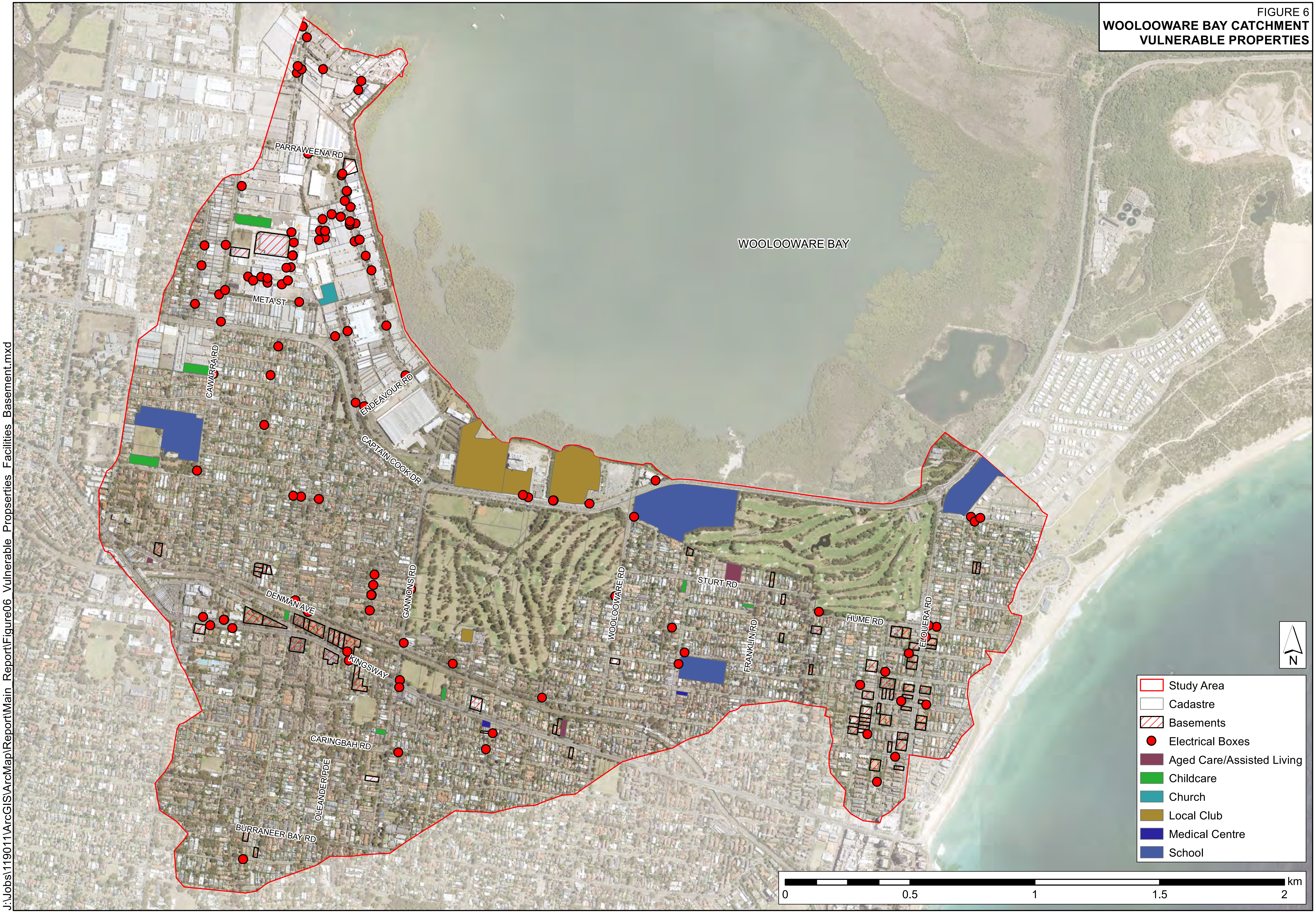

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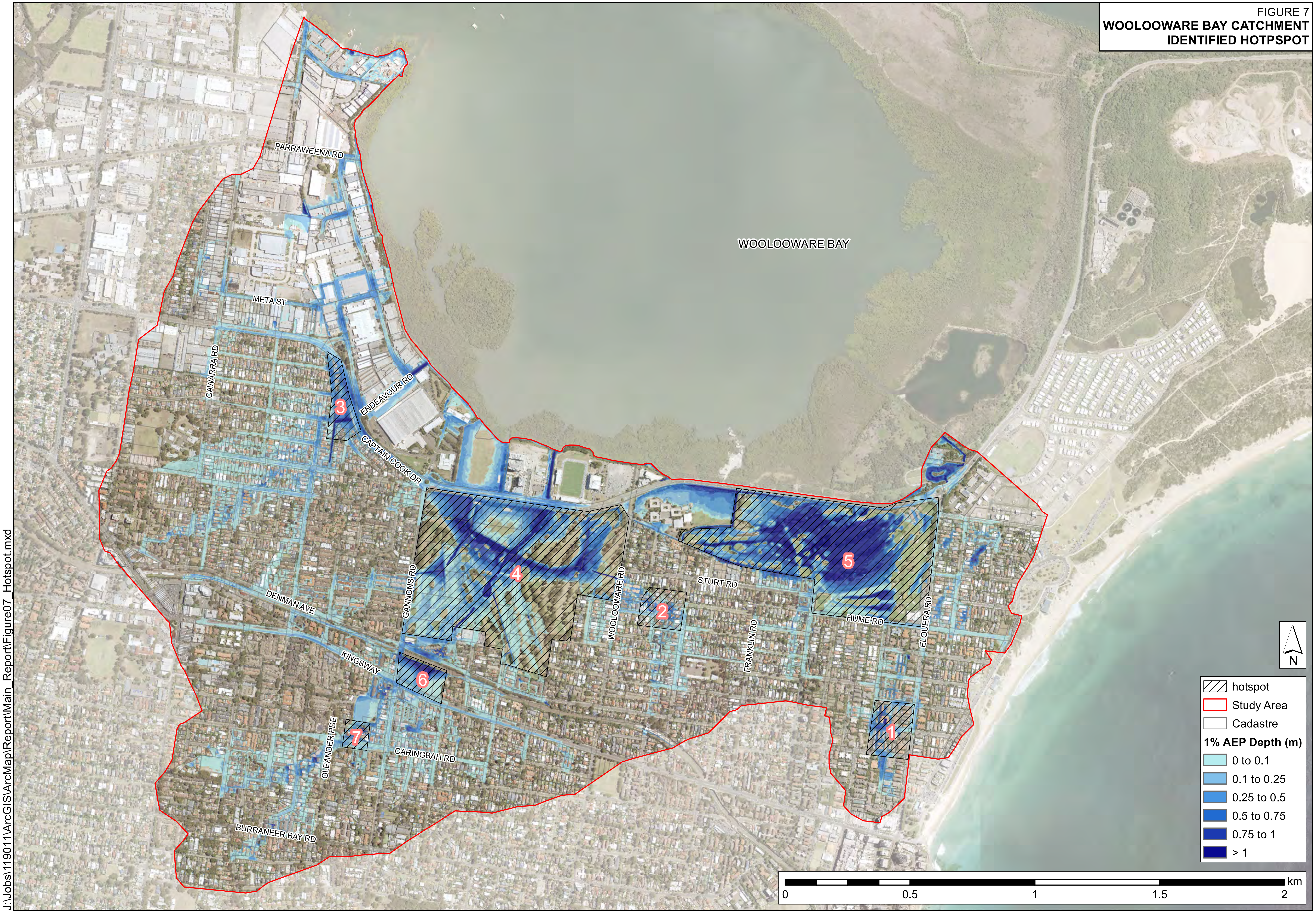
FIGURE 7
WOOLOOWARE BAY CATCHMENT IDENTIFIED HOTSPOT



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Appendix A: Glossary of Terms

Appendix A

APPENDIX A: GLOSSARY

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, Government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity

	of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.

flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the flood liable land concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPLs are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the standard flood event in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.

hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves: • the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or • water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or • major overland flow paths through developed areas outside of defined drainage reserves; and/or • the potential to affect a number of buildings along the major flow path.
mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.
minor, moderate and major flooding	Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: **minor flooding:** causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. **moderate flooding:** low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. **major flooding:** appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
modification measures	Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.

peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to water level. Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

ARR 2019 Modelling Results

Appendix B

APPENDIX B: ARR 2019 MODELLING RESULTS

B1: TUFLOW Modelling Methodology

The following sections describe how key features were accounted for in the TUFLOIW modelling.

This project was completed over a period of three years and during that time several large and small changes to the TUFLOW model have been undertaken. All mapping, modelling and result files in Appendix B and provided to Council have adopted the most up to date TUFLOW model. The early comparison results provided in Appendix C were undertaken using prior TUFLOW models and for various technical and other reasons these results could not be subsequently updated using the final TUFLOW model. Thus, these model runs cannot now be exactly replicated.

B1.1 Road Kerbs and Gutters

LiDAR / ALS typically do not have sufficient resolution to adequately define the kerb and gutter system within roadways. The density of the aerial survey points is in the order of one per square metre, and the kerb/gutter feature is generally of a smaller scale than this, so the LiDAR does not pick up a continuous line of low points defining the drainage line along the edge of the kerb. To deal with this issue Engineers Australia: Australian Rainfall and Runoff Revision Project 15: *Two Dimensional Modelling in Urban and Rural Floodplains. Department of Climate Change and Energy Efficiency*, November 2012 provides the following guidance:

"*Stamping a preferred flow path into a model grid/mesh (at the location of the physical kerb/gutter system) may produce more realistic model results, particularly with respect to smaller flood events that are of similar magnitude to the design capacity of the kerb and gutter. Stamping of the kerb/gutter alignment begins by digitising the kerb and gutter interval in a GIS environment. This interval is then used to select the model grid/mesh elements that it overlays in such a way that a connected flow path is selected (i.e. element linkage is orthogonal). These selected elements may then be lowered relative to the remaining grid/mesh.*"

The road gutter network plays a key role for overland flow in the urbanised parts of the study area. To model the system effectively, the gutters were stamped into the mesh using the method described above. The method used was to digitise breaklines along the gutter lines and reduce the ground levels along those model cells by 0.1 m, creating a continuous flow path in the model.

B1.2 Fencing and Obstructions

Smaller localised obstructions (such as fences) can be represented in TUFLOW in several ways including as impermeable obstructions, a percentage blockage or as an energy loss. The obstructions may also be approximated generally by increasing Manning's "n" roughness for certain land use areas (such as residential) to represent the typical type of fencing used in such areas.

Individual fences in the catchment were not explicitly modelled, as they are difficult to identify and relatively impermanent (since people can change their fences without Council approval). Fences in urbanised areas were therefore accounted for by applying a slightly higher Manning's "n" roughness for the residential land-use type to simulate the obstruction to flow.

B1.3 Buildings

Buildings and other significant features likely to act as flow obstructions were incorporated into the model network based on building footprints, defined using aerial photography. These types of features were modelled as impermeable obstructions to flow. Thus, there is no assumed flood storage capacity within the building. Building delineation was based on aerial photographs and validated for key overland flow areas by site inspection and use of Google "Streetview" photographs.

Buildings were "blocked out" from the 2D model grid, in line with research undertaken for the Australian Rainfall and Runoff Revision Project 15 mentioned above. The research project found that:

"*Numerical model trials showed that on the basis of the available data sets, the best performing method when representing buildings in a numerical model was to either remove the computational points under the building footprint completely from the solution or to increase the elevation of the building footprint to be above the maximum expected flood height."*

The project also found that:

"Analysis of flood volumes on the floodplain has shown that in a floodplain with flows passing through the floodplain, achieving peak levels due to peak flow rate rather than peak stored volume, the influence of the flow volume stored inside buildings is not significant to the presented flood levels in the prototype floodplain."

B2: Inclusion of the ARR 2019 Methodology

As detailed in Section 3.2 there are significant changes with the adoption of 2019 methodology. These are discussed below together with a description of the results.

B2.1 Critical Duration Analysis

The TUFLOW model was run for the 10 rainfall temporal patterns for the following durations: 30, 60, 120, 180, 360, 540 and 720 minutes. Image B1 indicates the critical durations across the catchment for the 1% AEP event. No single duration is dominant with the 30-minute critical in the upper catchment and the longer durations in the lower catchment near Woolooware Bay.

To simplify the number of durations to be mapped, peak levels from the 30, 120 and 540-minute durations (1% AEP event) were enveloped to obtain the peak value and compared to the envelope of all the critical durations. The results are shown on Image B2 which indicates minimal differences. Consequently these 3 durations were adopted to define the critical storm duration.

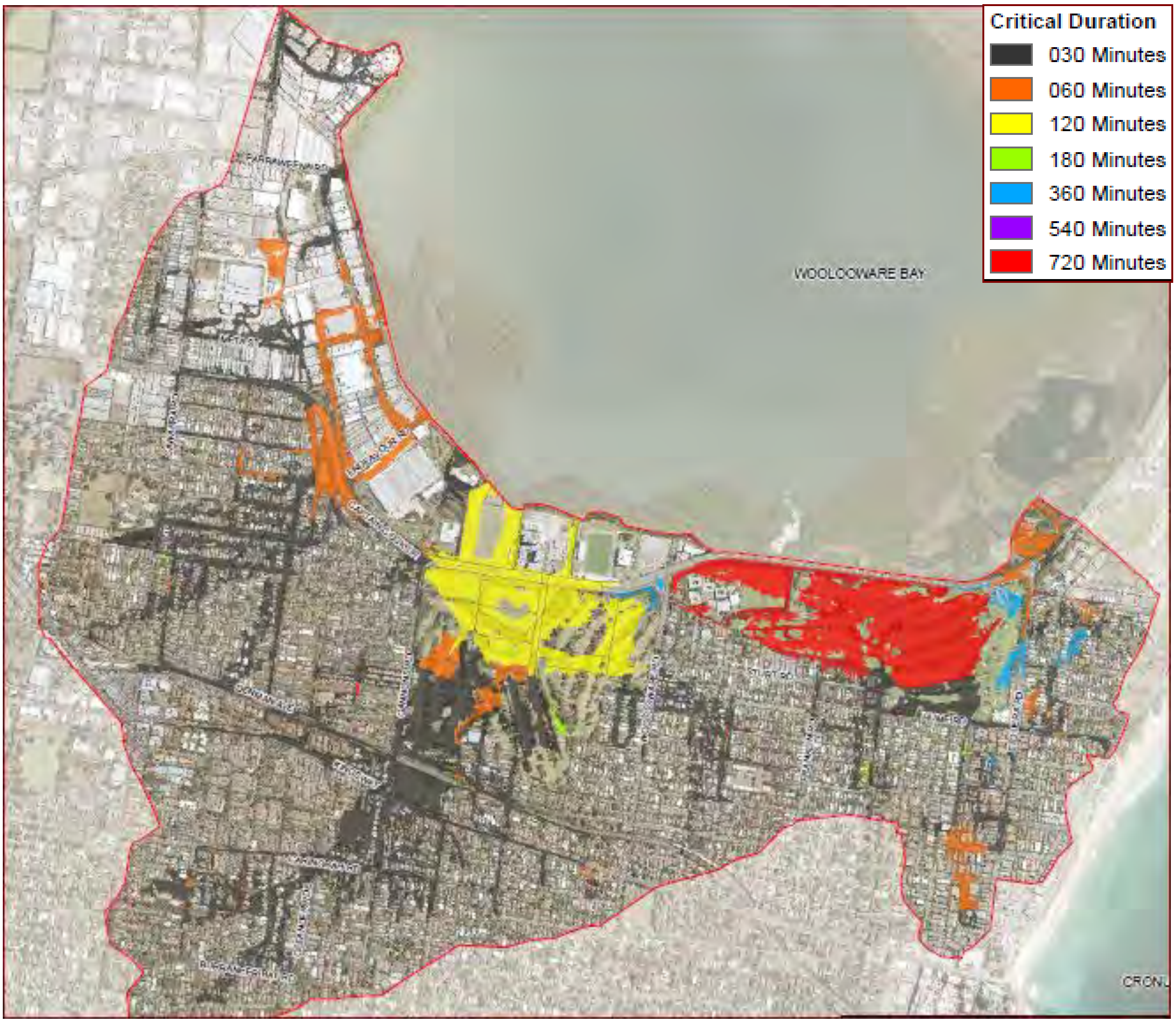

Image B1: Critical Durations 1% AEP

Image B2: Comparison of Enveloped 30, 120 and 540 minute durations v Envelope of all Durations

B2.2 Effect of Design Ocean Scenario

Design flood levels for land near the coast are derived from a combination of ocean influence and rainfall over the catchment. There is a 1% AEP event in the ocean and a 1% AEP rainfall event over the catchment. However, it would be unrealistic that both 1% AEP events would occur at the same time as they are produced from different meteorologic conditions, although in many storm events they occur in the same storm though not at the same time. The June 2007 "Pasha Bulker" storm in Newcastle is a good example where high rainfall and ocean conditions occur in the same storm.

Table 3 and Table 4 provide the peak design ocean levels and the methodology for linking the ocean and rainfall events. It will be noted that the design scenarios smaller than the 2% AEP are identical (Table 4). For the 1% AEP there is little difference in the adopted peak ocean level (1.7 mAHD for the ocean envelope compared to 1.5 mAHD for the rainfall envelope).

B3 Results

B3.1 Design Flood Results

Updated design flood extents, depth and level contours are provided on Figure B1 to Figure B8 and peak velocities on Figure B9 to Figure B12.

Hydraulic hazard and hydraulic categorisation are discussed in Section 3.6 with figures provided on Figure B13 to Figure B16 and Figure B17 to Figure B20 respectively.

B3.2 Design Flood Sensitivity Results

The effect of a 10%, 20% and 30% rainfall increase for the 1% AEP and PMF events are provided on Figure B21 to Figure B28.

The effects of an assumed +0.23 sea level rise by the year 2050 and assumed +0.72 sea level rise by the year 2100 for the 1% AEP and PMF events are provided on Figure B29 to Figure B34.

B3.3 Capacity of Stormwater System

The capacity of the stormwater system (i.e., which is the largest AEP event that can be carried by each pipe in the network) is provided on Figure B35 and Figure B36.

B3.4 Flood Planning Figures

Flood Emergency Response Classifications are provided on Figure B37 with Figure B38 indicating the Flood Planning Constraints Categorisation and Figure B39 the Flood Risk Precincts.

FIGURE B1
WOOLOOWARE BAY CATCHMENT
PEAK FLOOD DEPTH AND LEVEL CONTOUR
0.2 EY EVENT
2019 AR&R

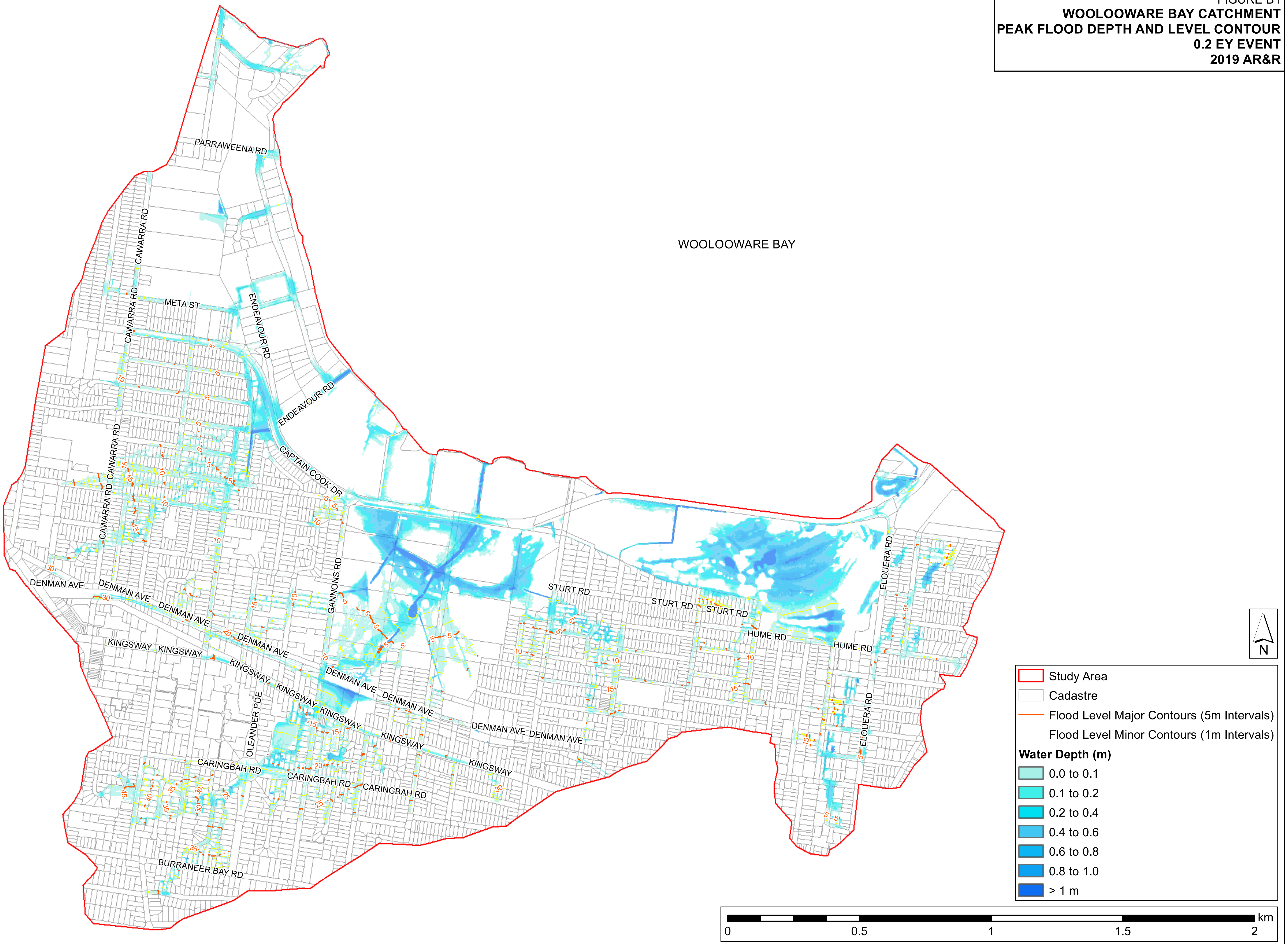

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FIGURE B2
WOOLOOWARE BAY CATCHMENT
PEAK FLOOD DEPTH AND LEVEL CONTOUR
10% AEP EVENT
2019 AR&R

Study Area
Cadastre
Flood Level Major Contours (5m Intervals)
Flood Level Minor Contours (1m Intervals)
Water Depth (m)
0.0 to 0.1
0.1 to 0.2
0.2 to 0.4
0.4 to 0.6
0.6 to 0.8
0.8 to 1.0
> 1 m

0 0.5 1 1.5 2 km

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FIGURE B3

WOOLOOWARE BAY CATCHMENT
PEAK FLOOD DEPTH AND LEVEL CONTOUR
5% AEP EVENT
2019 AR&R

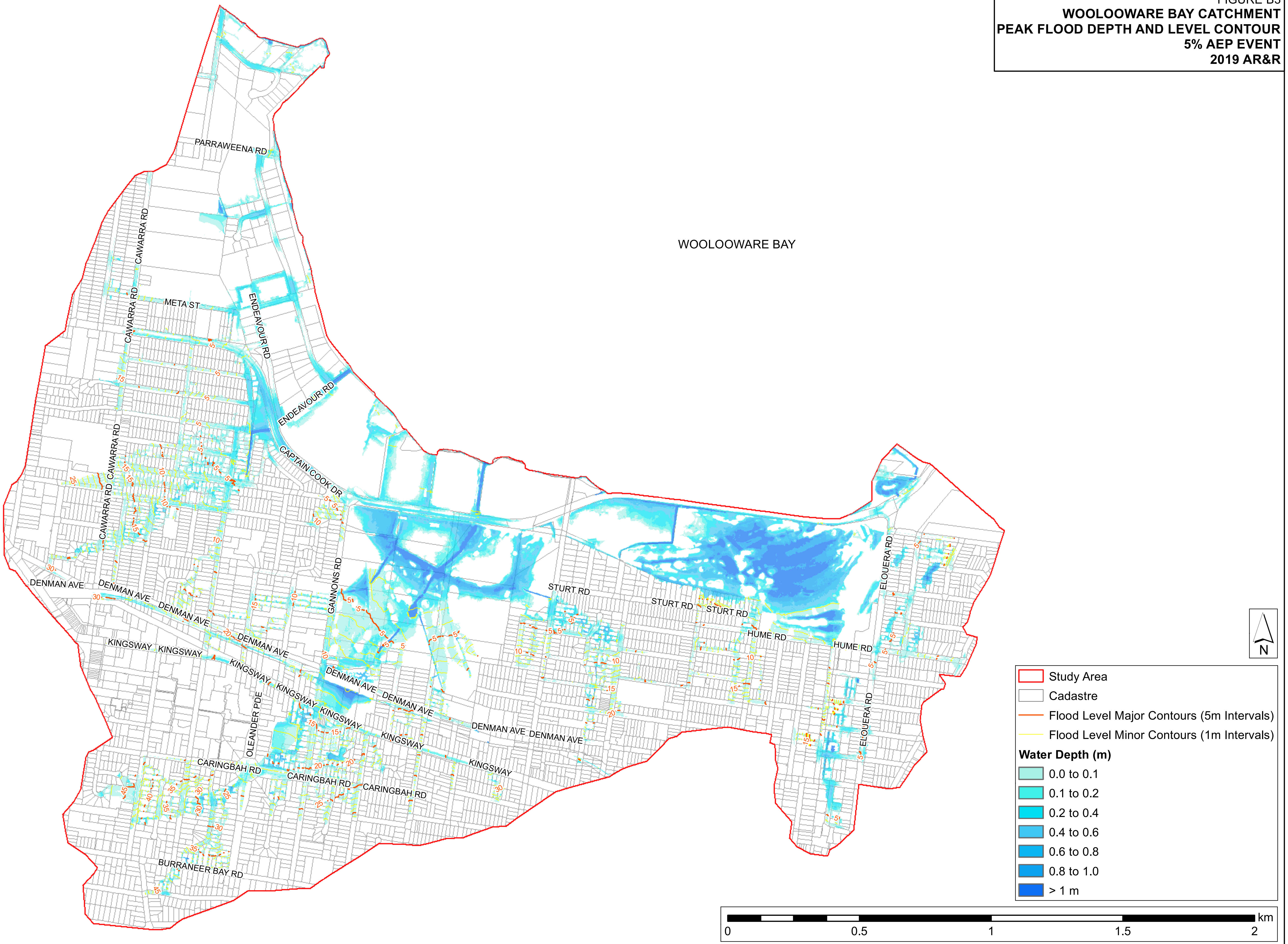

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FIGURE B4
WOOLOOWARE BAY CATCHMENT
PEAK FLOOD DEPTH AND LEVEL CONTOUR
2% AEP EVENT
2019 AR&R

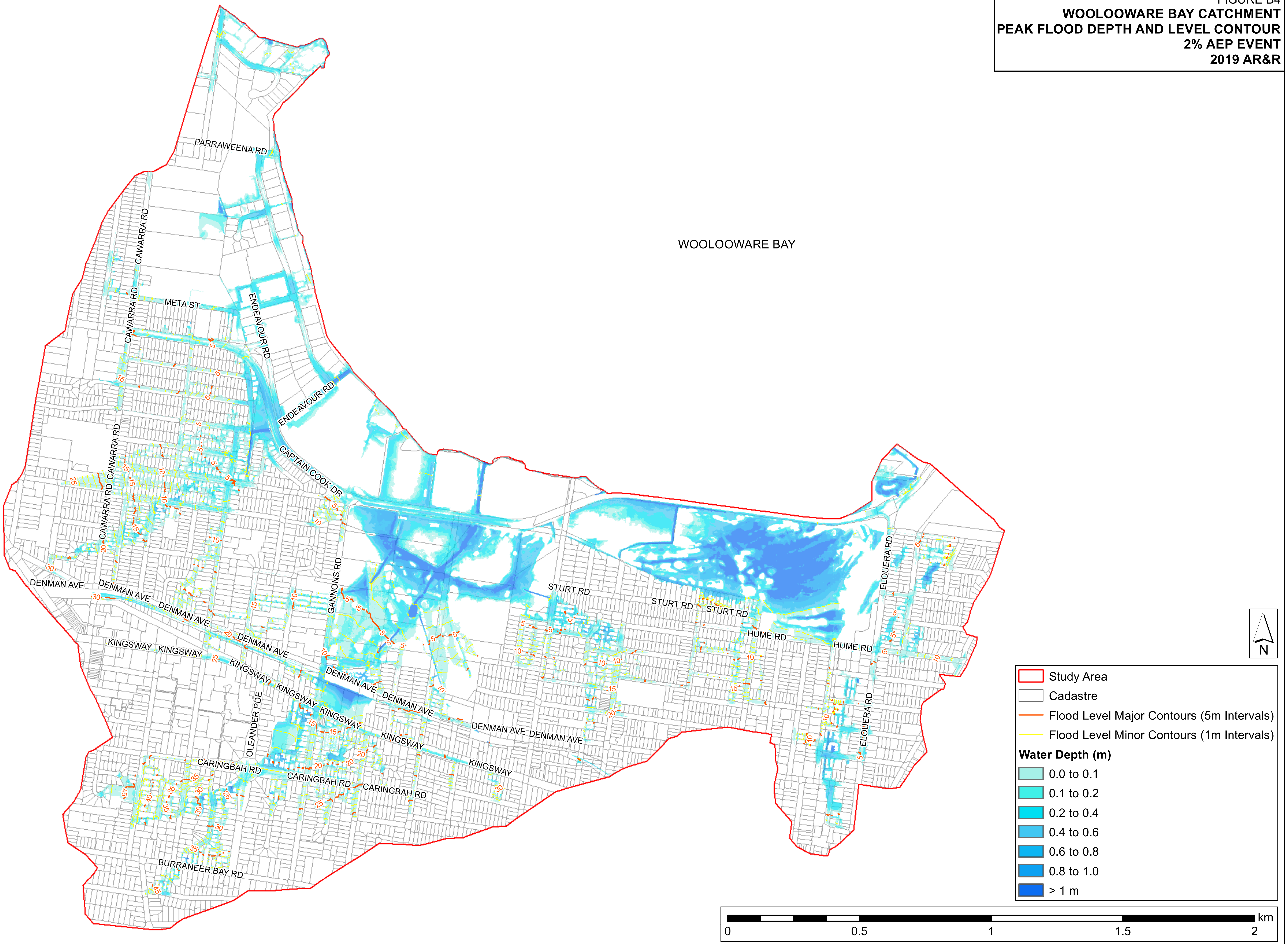

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FIGURE B5

WOOLOOWARE BAY CATCHMENT
PEAK FLOOD DEPTH AND LEVEL CONTOUR
1% AEP EVENT
2019 AR&R

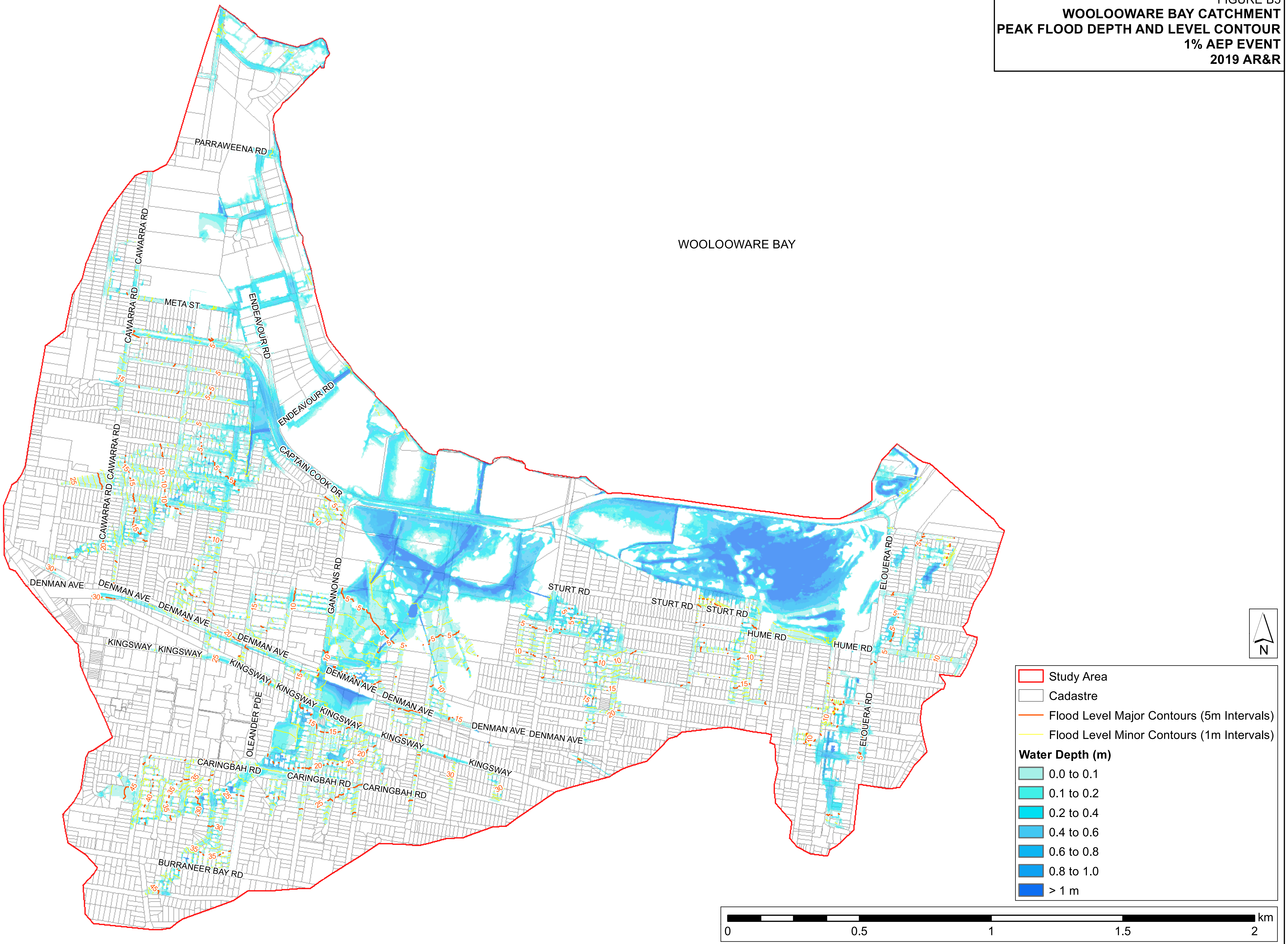

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FIGURE B6
WOOLOOWARE BAY CATCHMENT
PEAK FLOOD DEPTH AND LEVEL CONTOUR
0.5% AEP EVENT
2019 AR&R

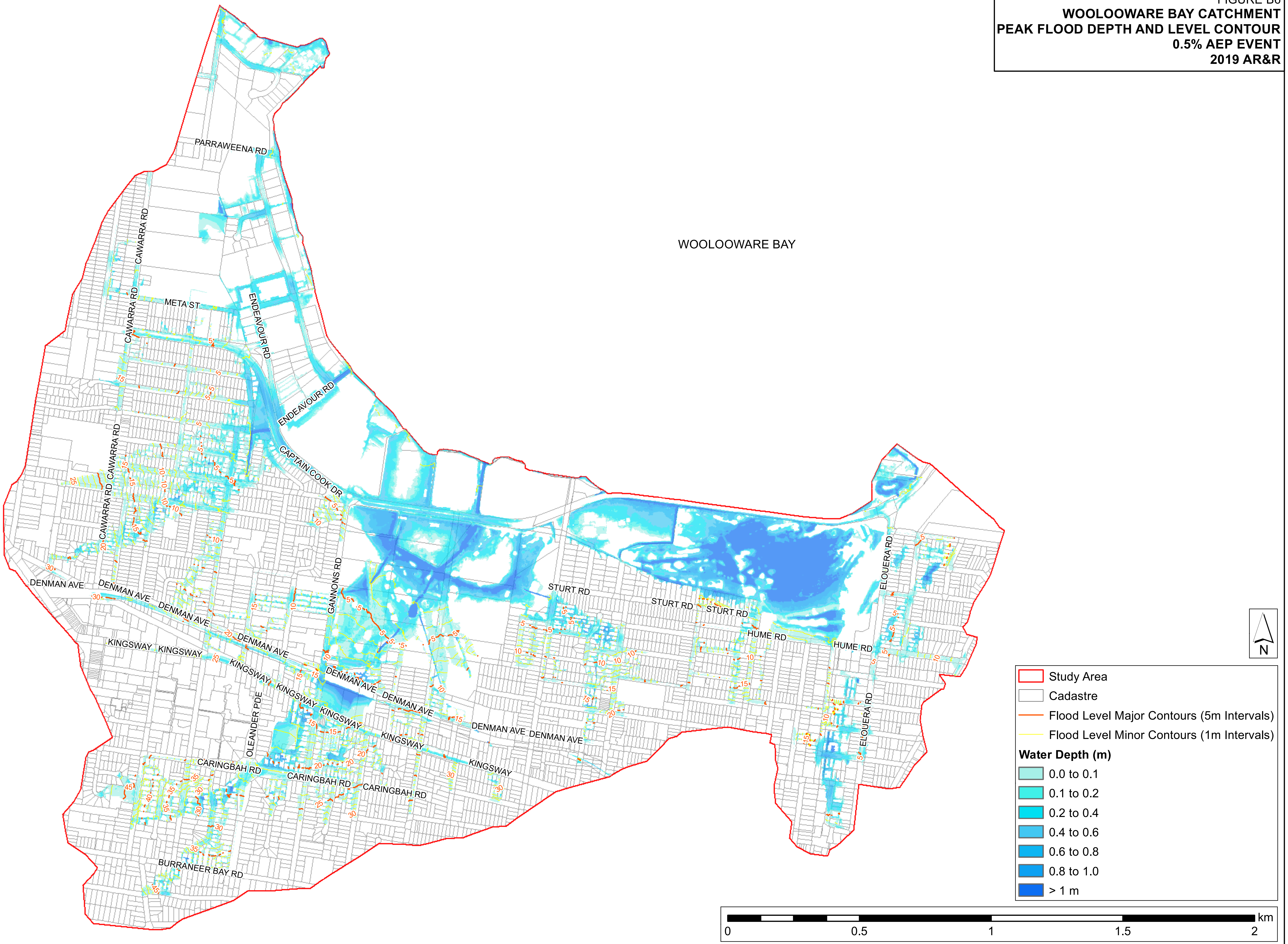

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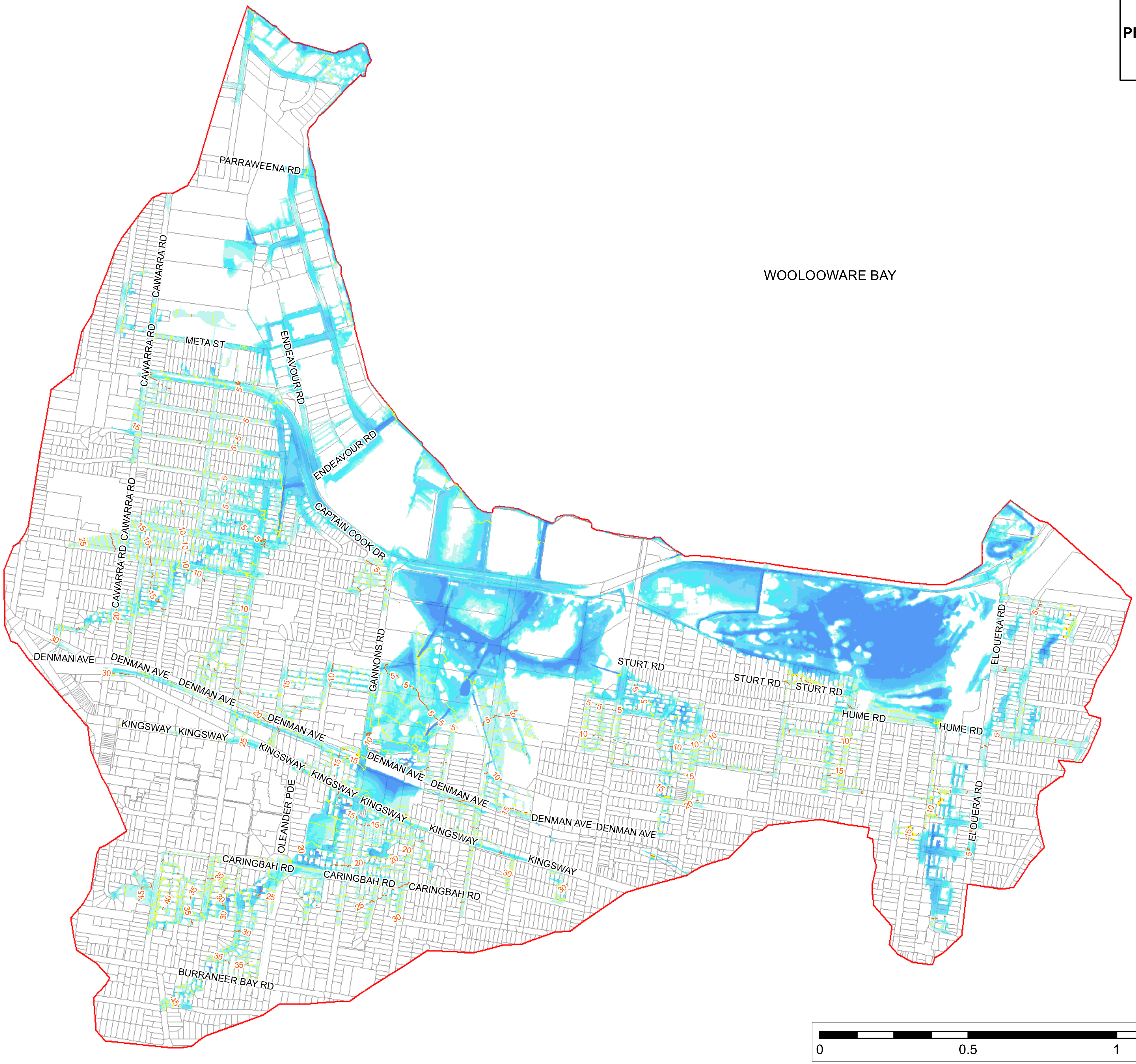
FIGURE B7
WOOLOOWARE BAY CATCHMENT
PEAK FLOOD DEPTH AND LEVEL CONTOUR
0.2% AEP EVENT
2019 AR&R



N

Study Area
Cadastre
Flood Level Major Contours (5m Intervals)
Flood Level Minor Contours (1m Intervals)
Water Depth (m)
0.0 to 0.1
0.1 to 0.2
0.2 to 0.4
0.4 to 0.6
0.6 to 0.8
0.8 to 1.0
> 1 m

0 0.5 1 1.5 2 km

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FIGURE B8
WOOLOOWARE BAY CATCHMENT
PEAK FLOOD DEPTH AND LEVEL CONTOUR
PMF EVENT
1987 AR&R

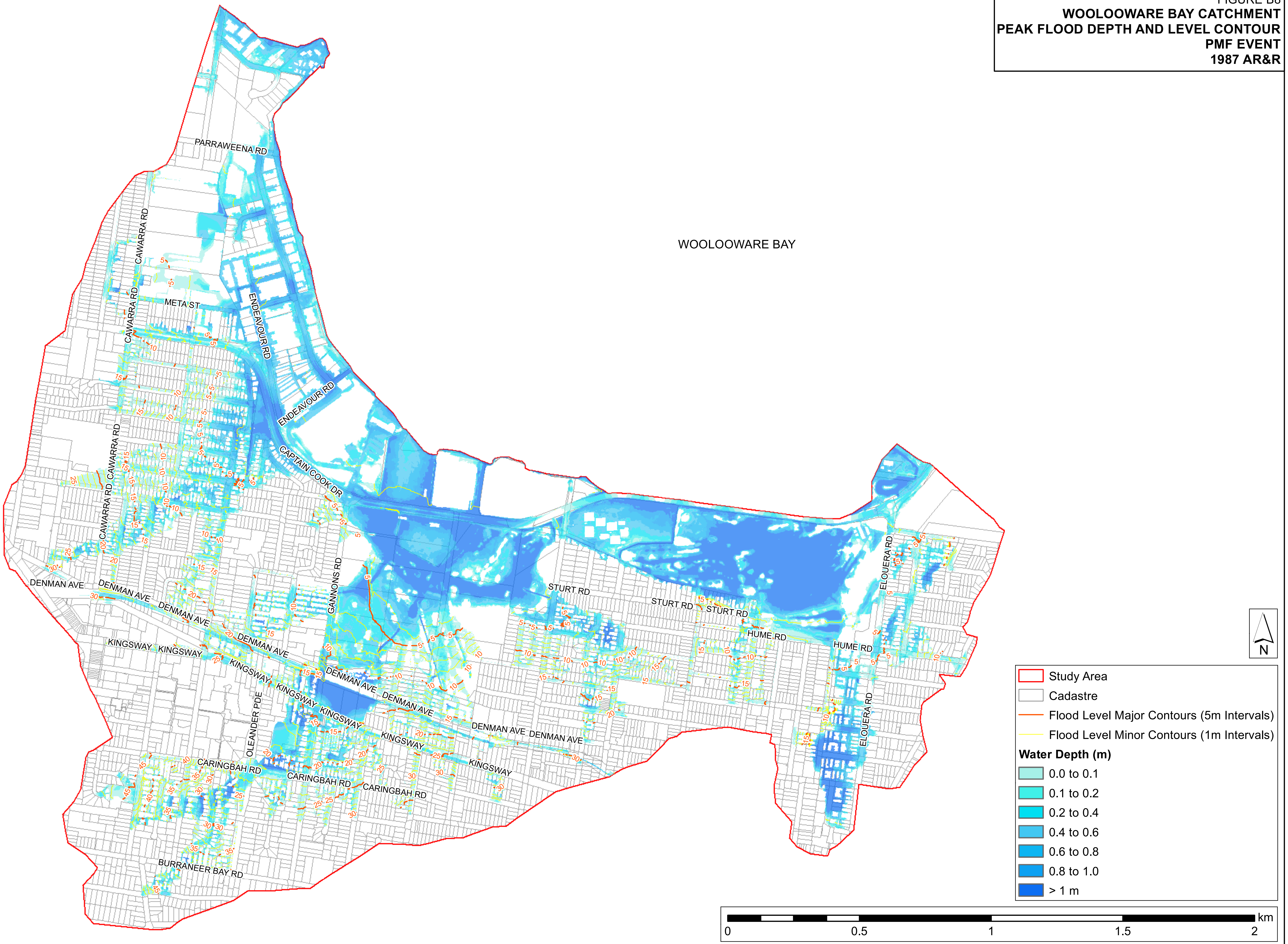

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FIGURE B9
WOOLOOWARE BAY CATCHMENT
PEAK FLOOD VELOCITY
5% AEP EVENT
2019 AR&R

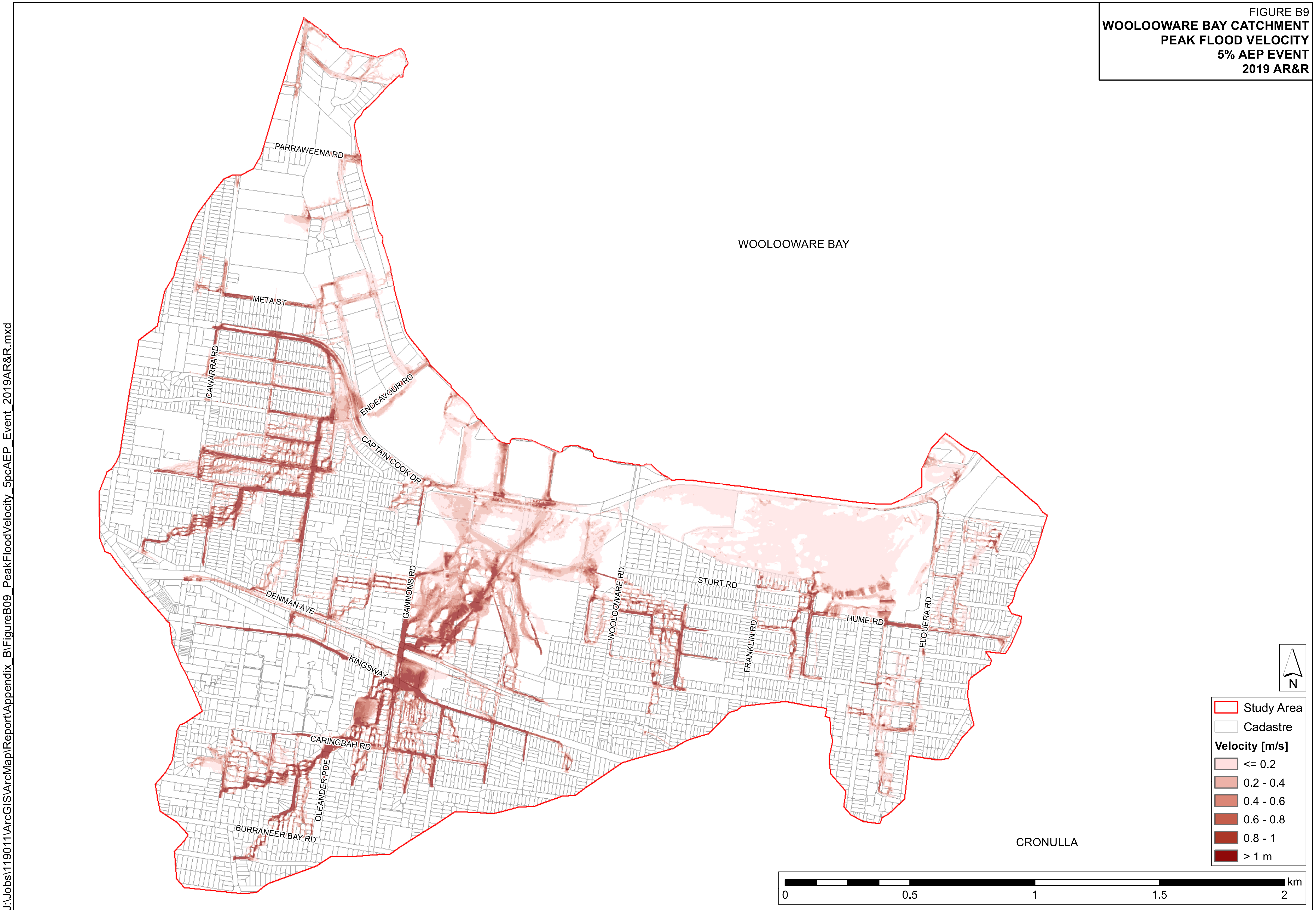

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FIGURE B10
WOOLOOWARE BAY CATCHMENT
PEAK FLOOD VELOCITY
1% AEP EVENT
2019 AR&R

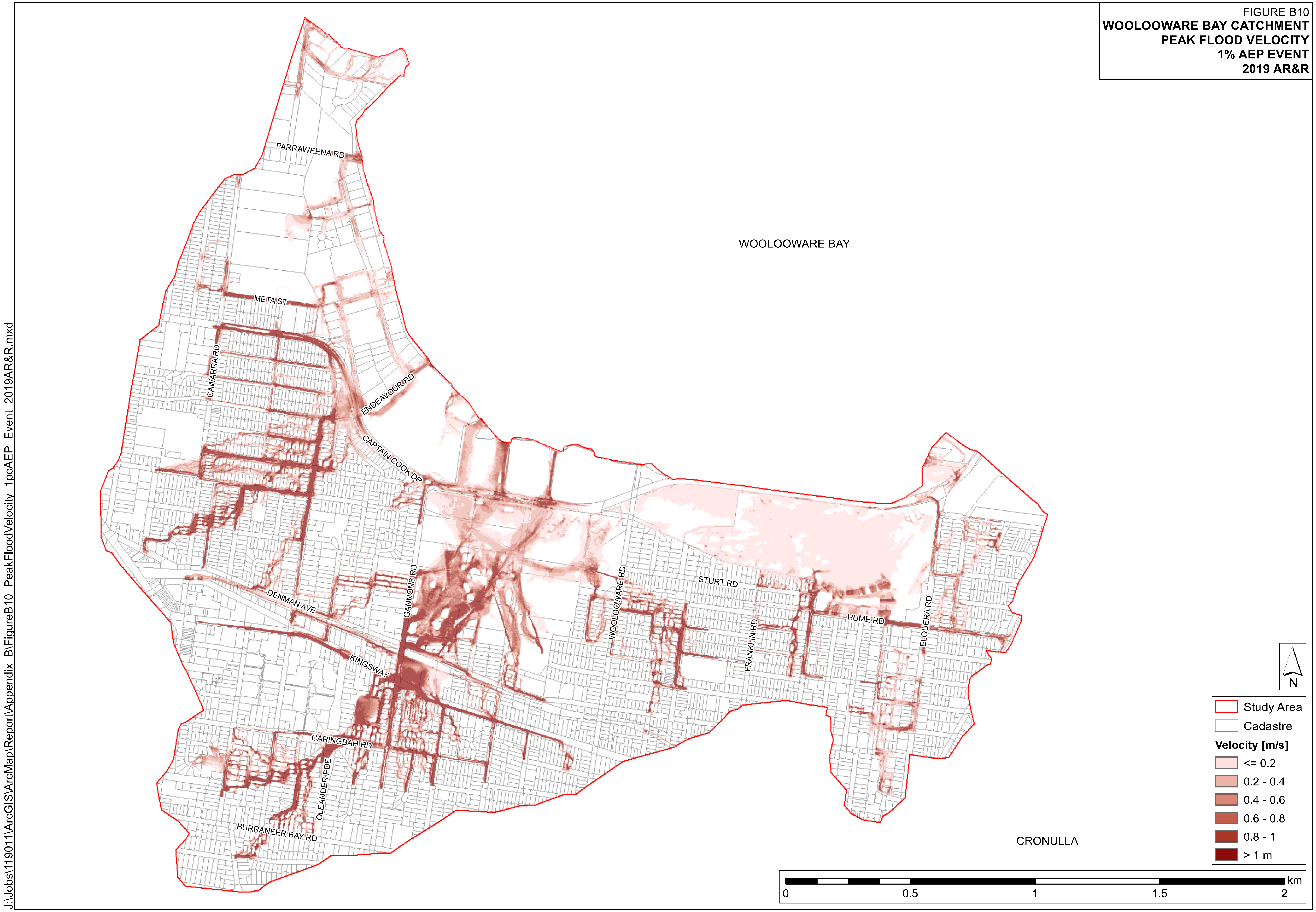

FIGURE B11
WOOLOOWARE BAY CATCHMENT
PEAK FLOOD VELOCITY
0.2% AEP EVENT
2019 AR&R

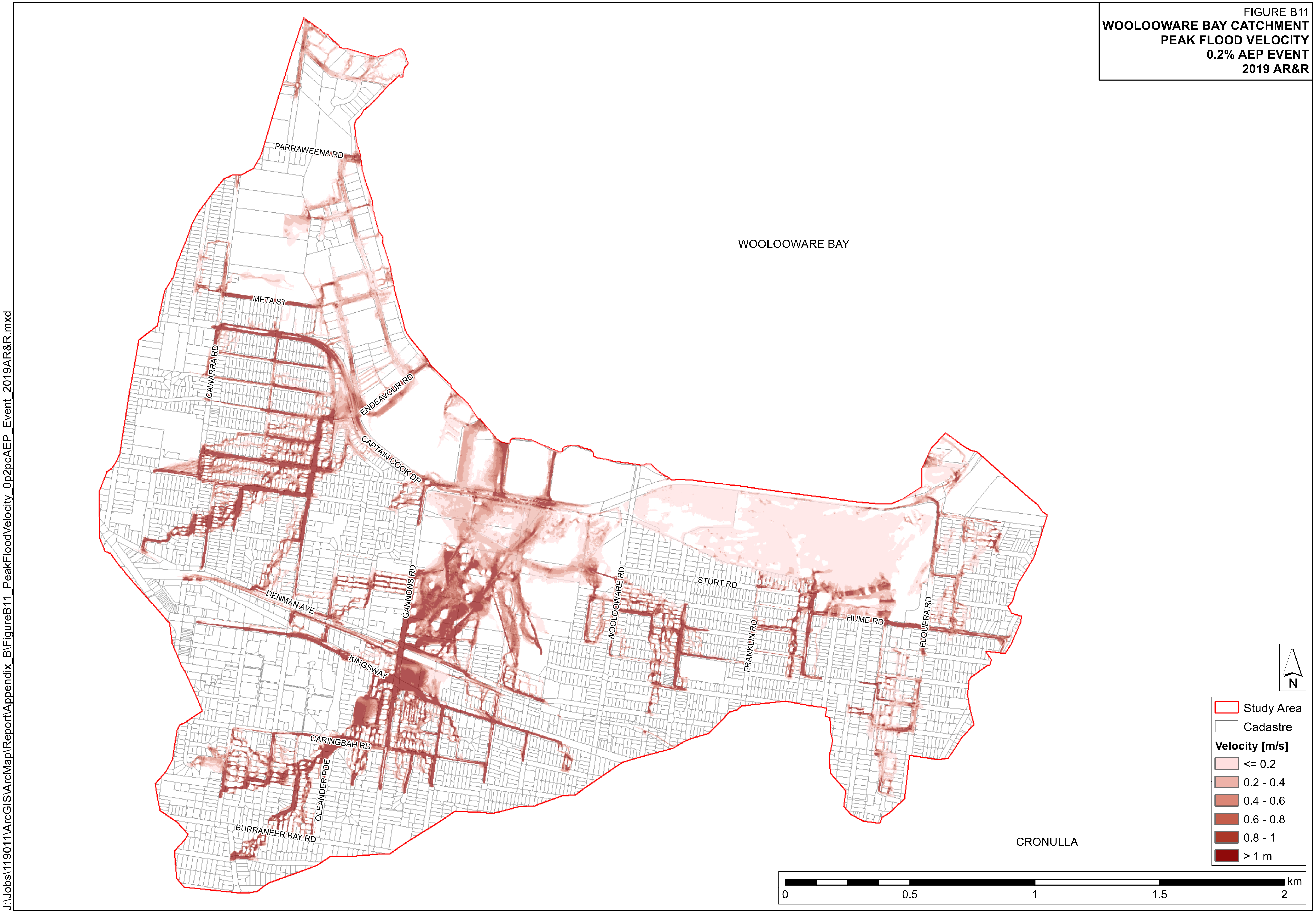

FIGURE B12
WOOLOOWARE BAY CATCHMENT
PEAK FLOOD VELOCITY
PMF EVENT
1987 AR&R

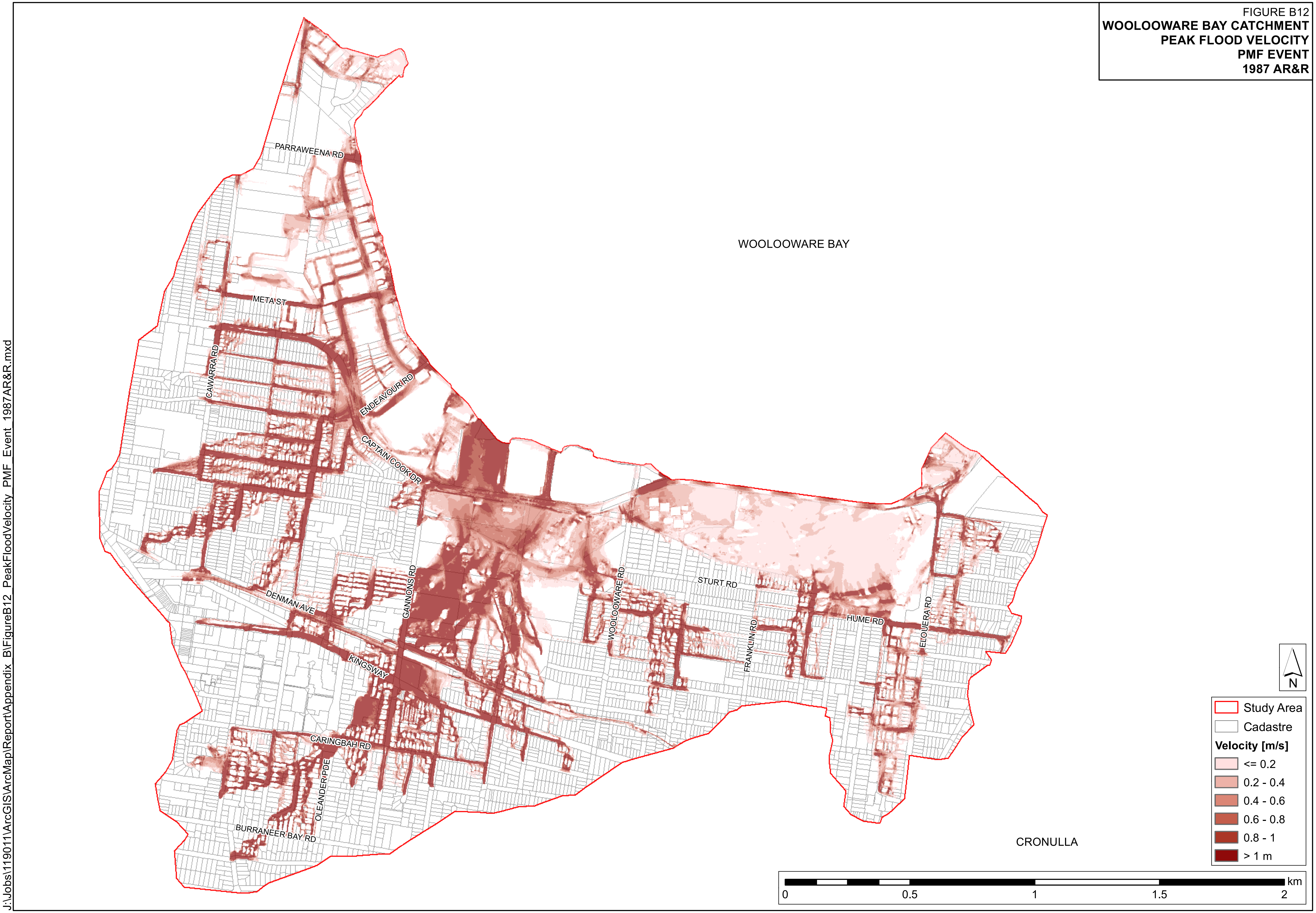

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FIGURE B13A
WOOLOOWARE BAY CATCHMENT
HYDRAULIC HAZARD
5% AEP EVENT
2019 AR&R

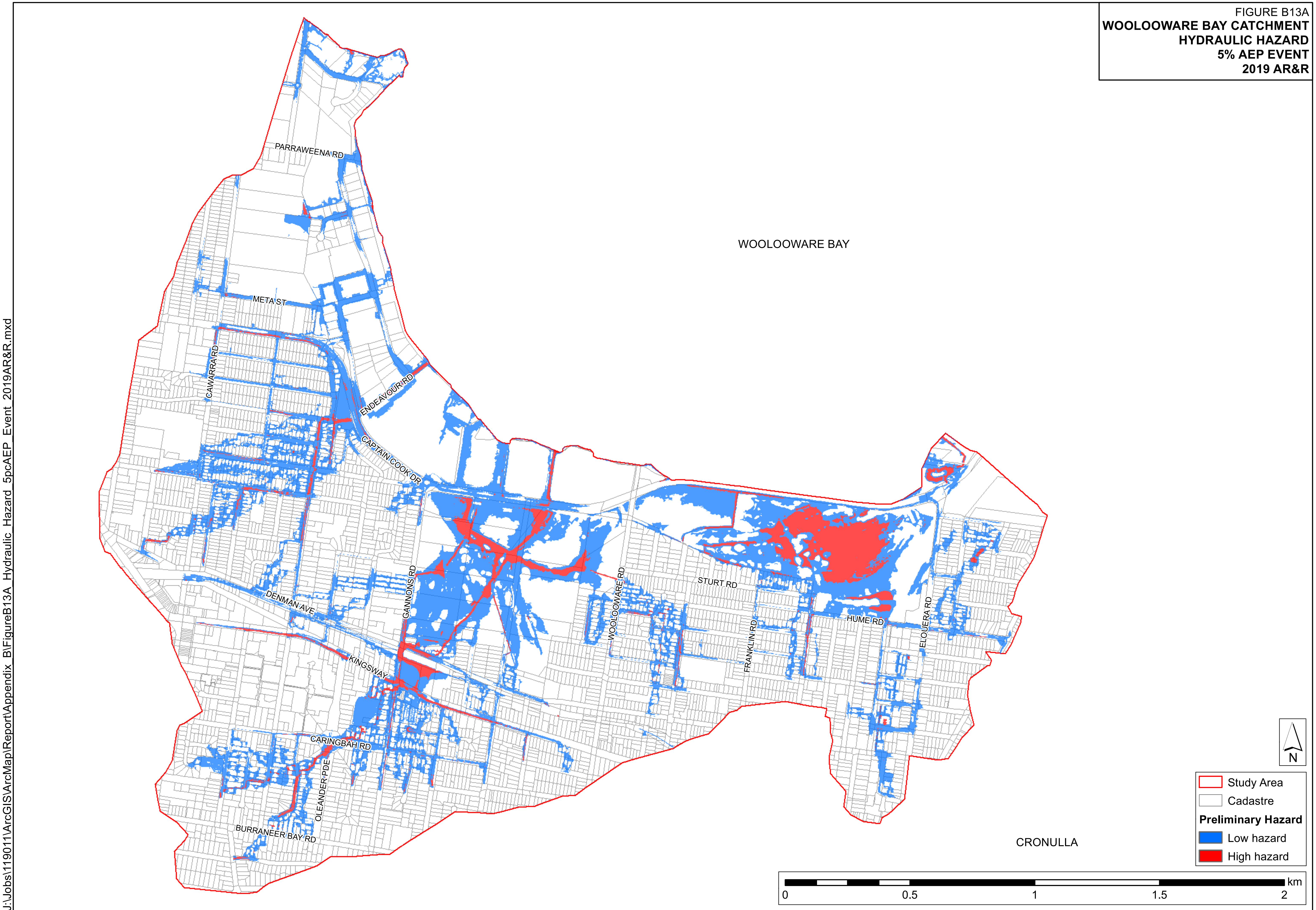

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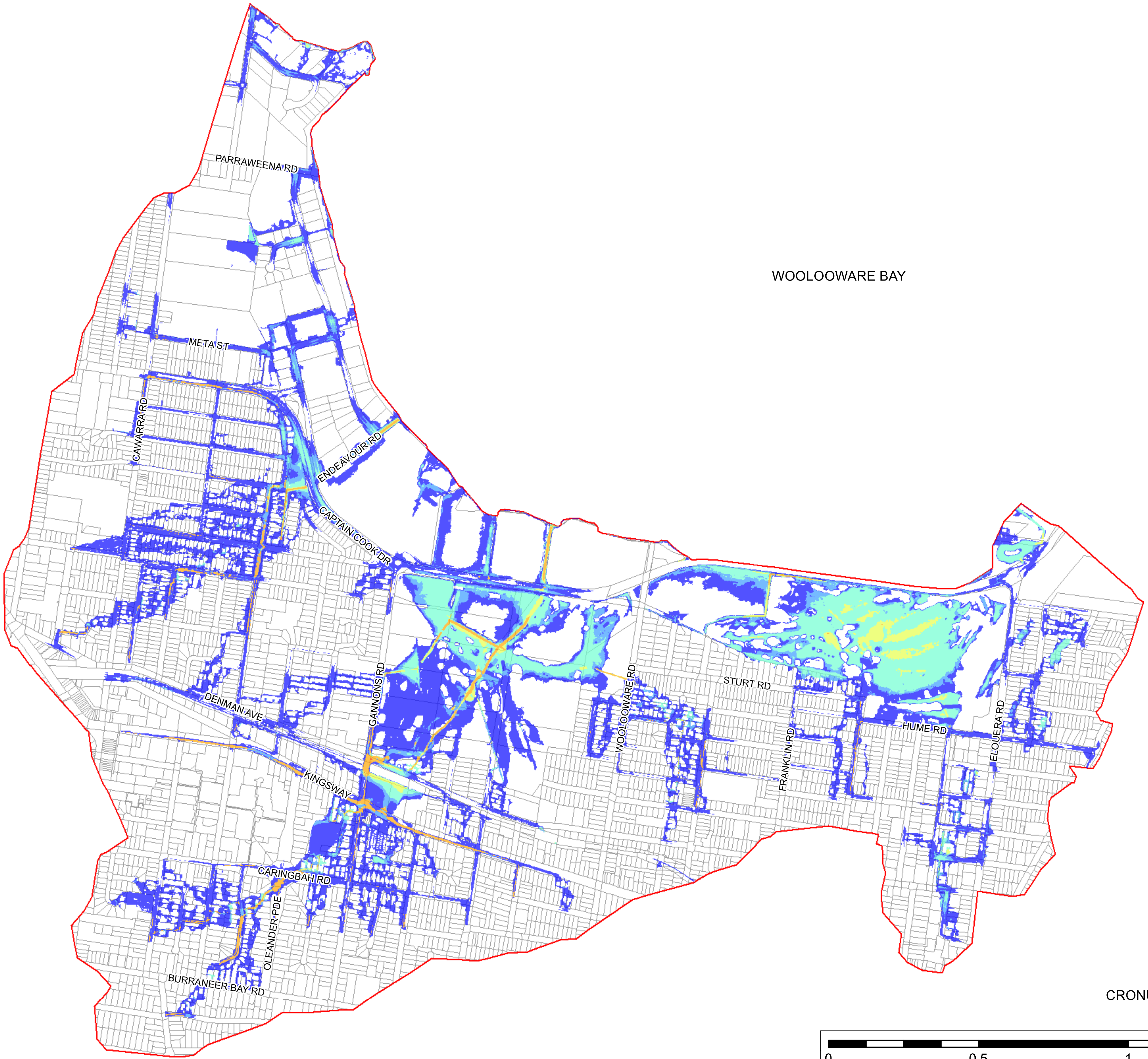
FIGURE B13
WOOLOOWARE BAY CATCHMENT
HYDRAULIC HAZARD
5% AEP EVENT
2019 AR&R



Study
Cadastre
Hydraulic Hazard
H1 - Generrally safe for people, vehicules and buildings
H2 - Unsafe for small
H3 - Unsafe for vehicles, children and the elderly
H4 - Unsafe for people and vehicles
H5 - Unsafe for people or vehicles. All Buildings Vulnerable to structural damage. Some less robust building types vulnerable to failure
H6 - Unsafe for vehicles and people. All Building Types considered vulnerable to failure

0 0.5 1 1.5 2 km

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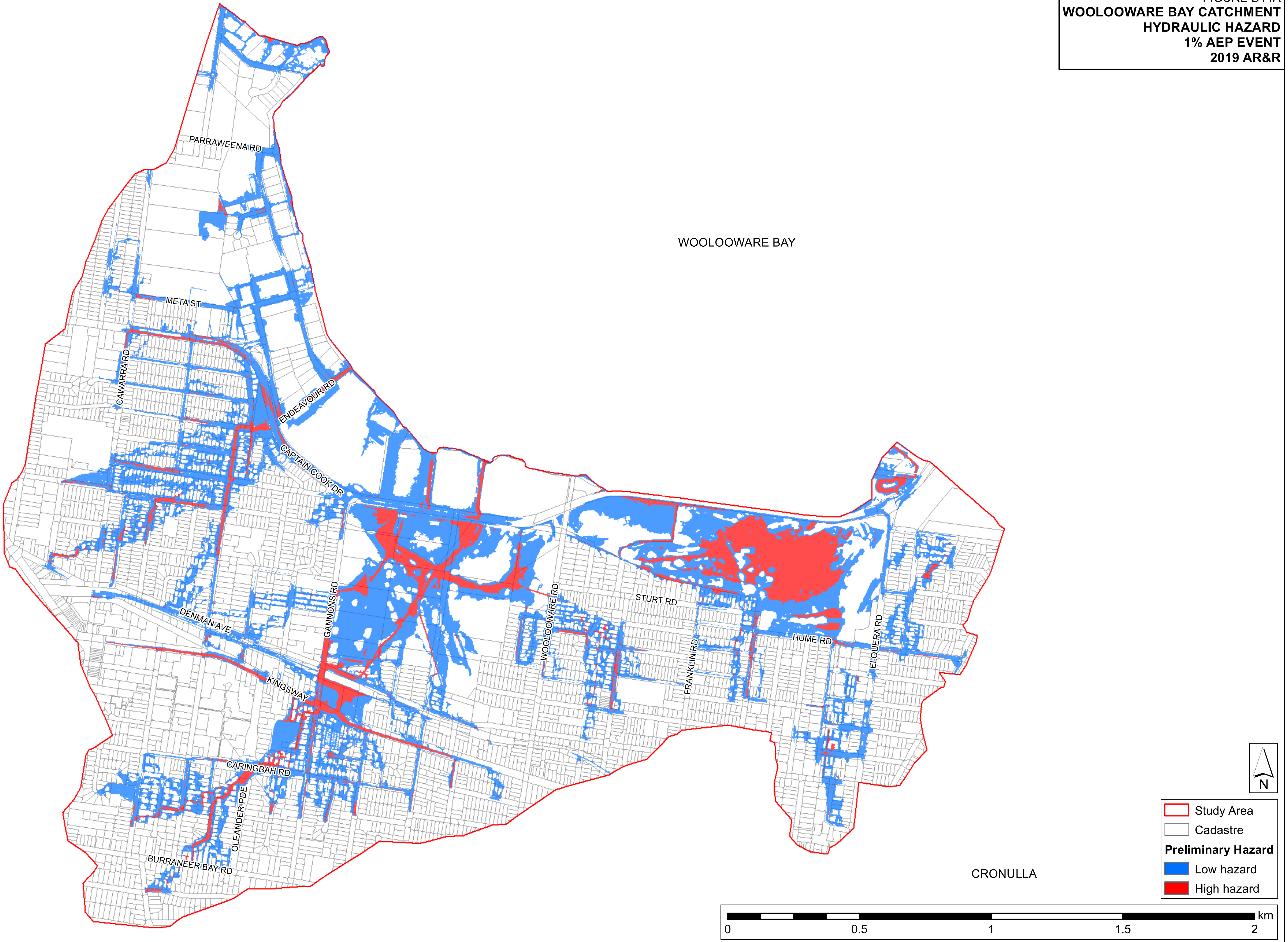
FIGURE B14A
WOOLOOWARE BAY CATCHMENT
HYDRAULIC HAZARD
1% AEP EVENT
2019 AR&R



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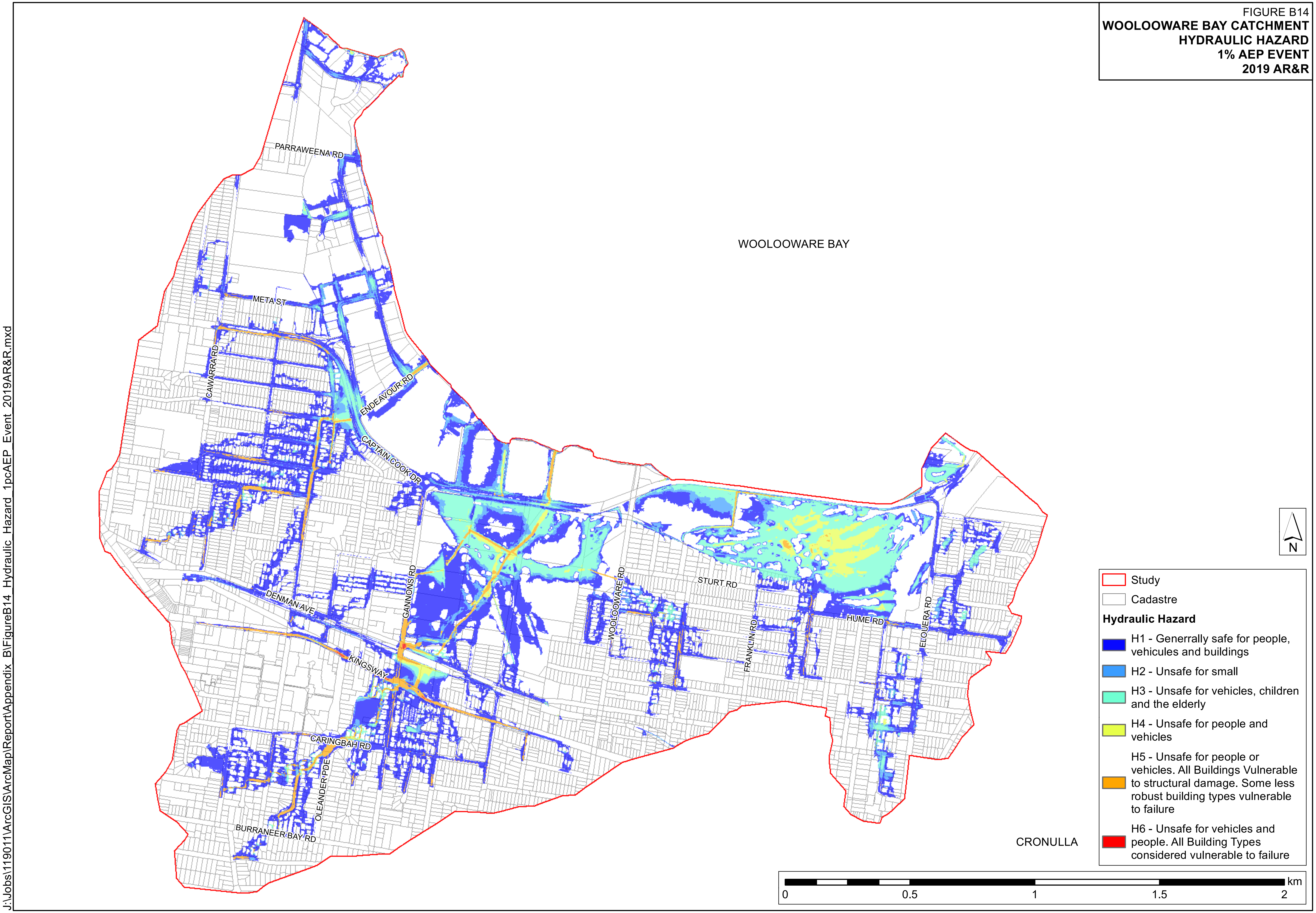


FIGURE B14
WOOLOOWARE BAY CATCHMENT
HYDRAULIC HAZARD
1% AEP EVENT
2019 AR&R
WOOLOOWARE BAY
PARRAWEENA RD
META ST
CAWARRA RD
ENDEAVOUR RD
CAPTAIN COOK DR
DENMAN AVE
GANNONS RD
KINGSWAY
CARINGBAH RD
OLEANDER PDE
BURRANEER BAY RD
WOOLOOWARE RD
STURT RD
FRANKLIN RD
HUME RD
ELOUERA RD
CRONULLA
N
Study
Cadastre
Hydraulic Hazard
H1 - Generrally safe for people, vehicules and buildings
H2 - Unsafe for small
H3 - Unsafe for vehicles, children and the elderly
H4 - Unsafe for people and vehicles
H5 - Unsafe for people or vehicles. All Buildings Vulnerable to structural damage. Some less robust building types vulnerable to failure
H6 - Unsafe for vehicles and people. All Building Types considered vulnerable to failure
0
0.5
1
1.5
2
km
J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB14_Hydraulic_Hazard_1pcAEP_Event_2019AR&R.mxd

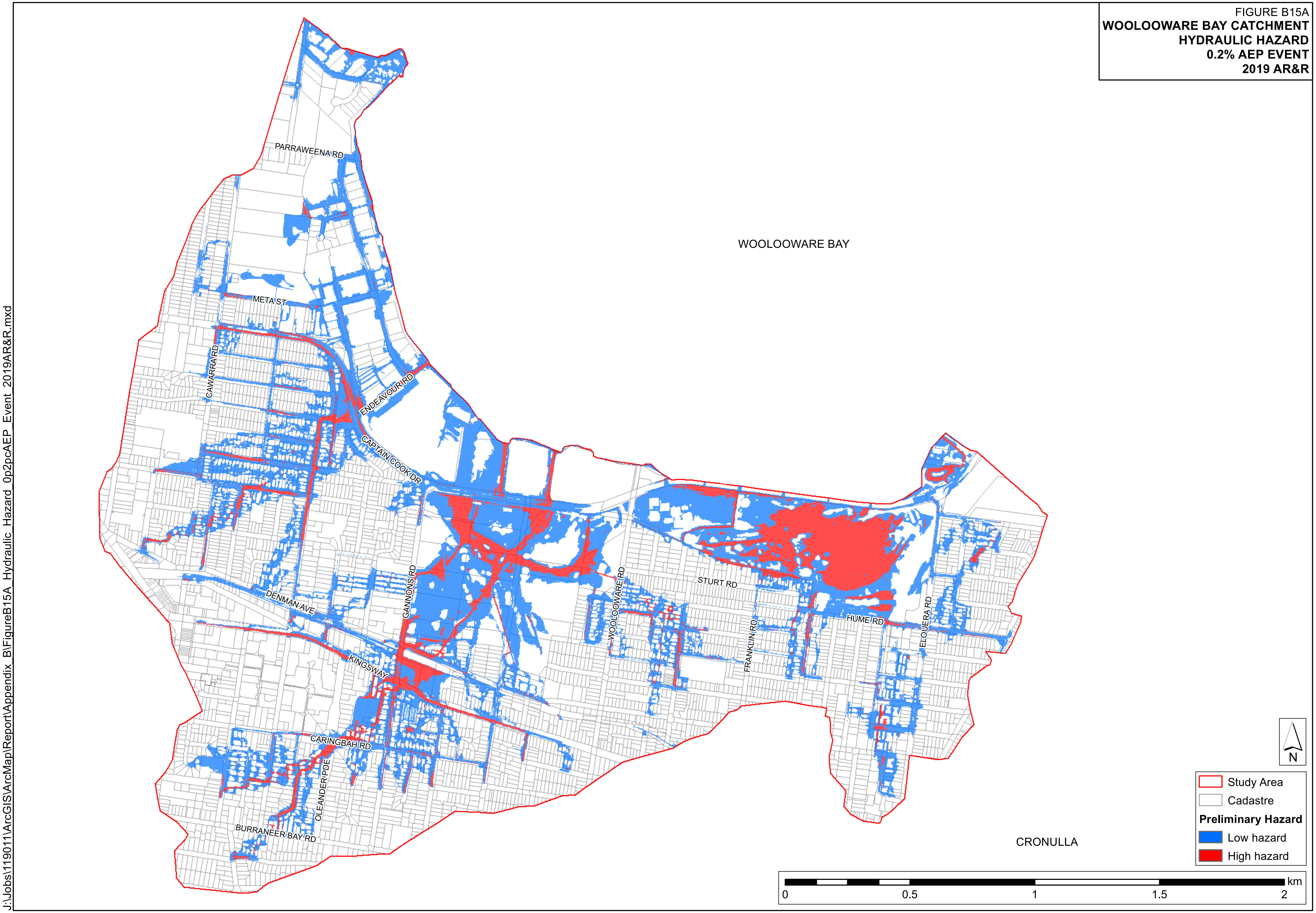
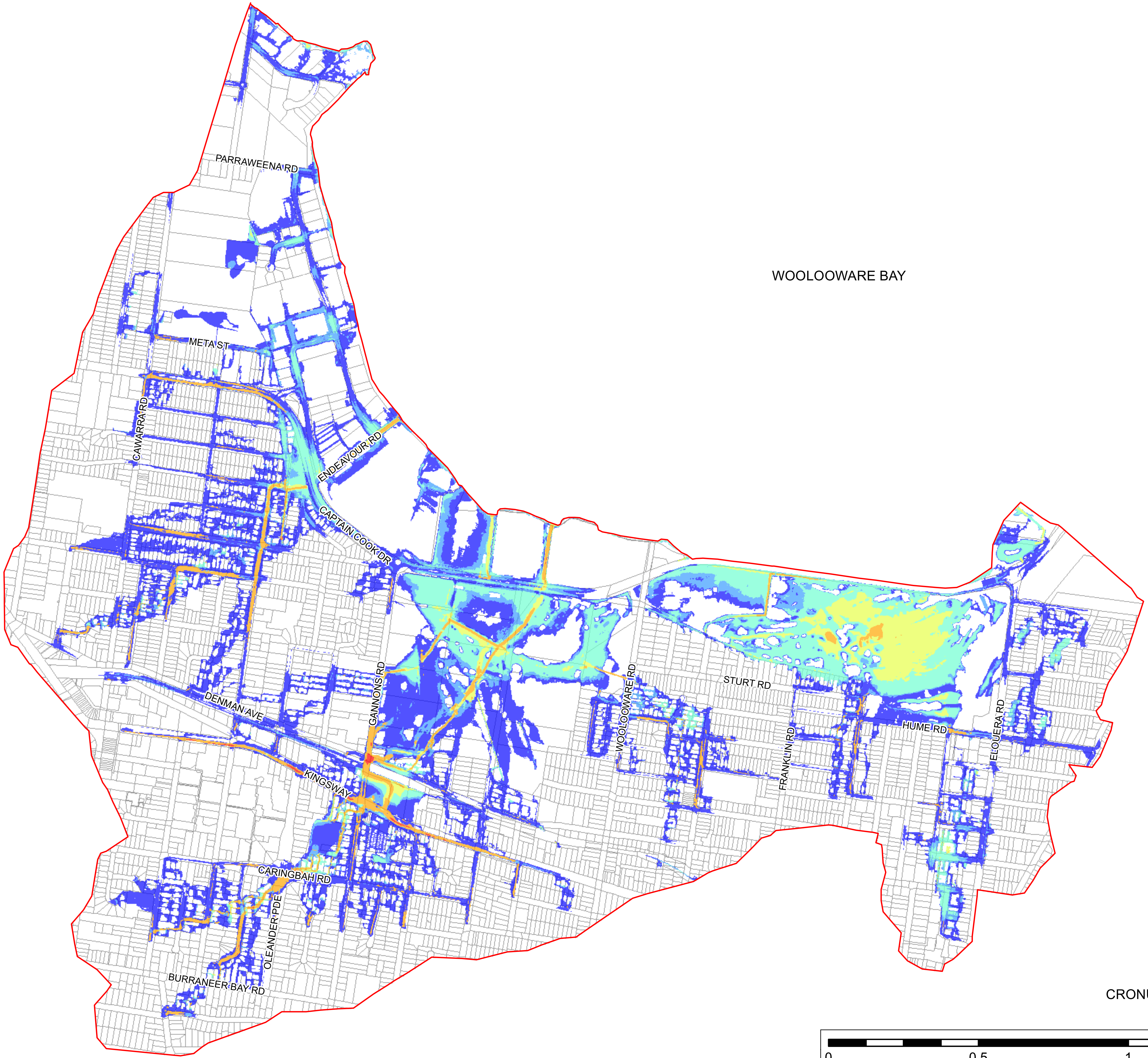


FIGURE B15A
WOOLOOWARE BAY CATCHMENT
HYDRAULIC HAZARD
0.2% AEP EVENT
2019 AR&R
WOOLOOWARE BAY
PARRAWEENA RD
META ST
CAWARRA RD
ENDEAVOUR RD
CAPTAIN COOK DR
DENMAN AVE
KINGSWAY
GANNONS RD
WOOLOOWARE RD
STURT RD
HUME RD
FRANKLIN RD
ELOUERA RD
CARINGBAH RD
OLEANDER PDE
BURRANEER BAY RD
CRONULLA
N
Study Area
Cadastre
Preliminary Hazard
Low hazard
High hazard
0
0.5
1
1.5
2
km
J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB15A_Hydraulic_Hazard_0p2pcAEP_Event_2019AR&R.mxd

FIGURE B15
WOOLOOWARE BAY CATCHMENT
HYDRAULIC HAZARD
0.2% AEP EVENT
2019 AR&R



N

Study

Cadastre

Hydraulic Hazard

H1 - Generrally safe for people, vehicules and buildings

H2 - Unsafe for small

H3 - Unsafe for vehicles, children and the elderly

H4 - Unsafe for people and vehicles

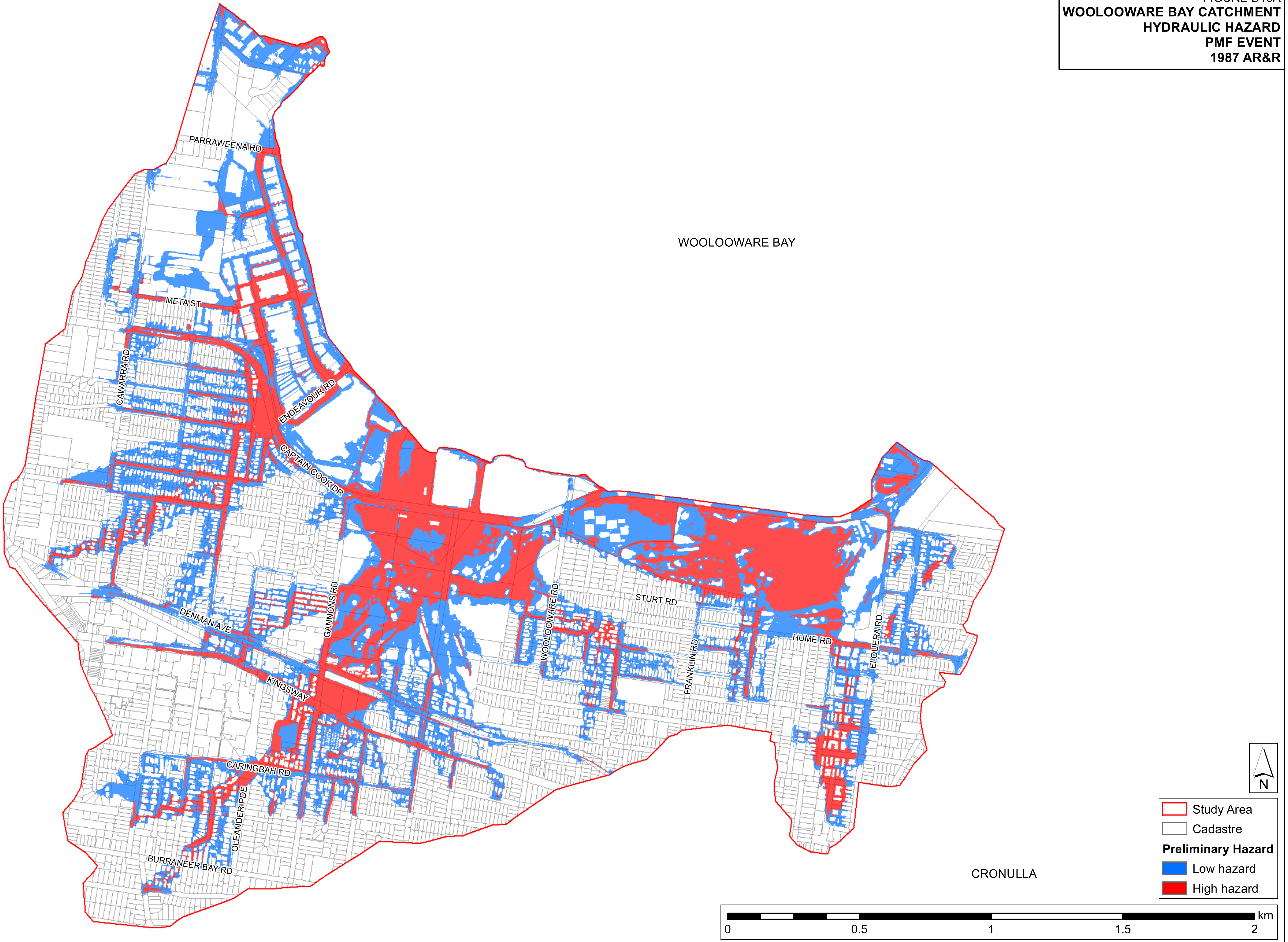
H5 - Unsafe for people or vehicles. All Buildings Vulnerable to structural damage. Some less robust building types vulnerable to failure

H6 - Unsafe for vehicles and people. All Building Types considered vulnerable to failure

0 0.5 1 1.5 2 km

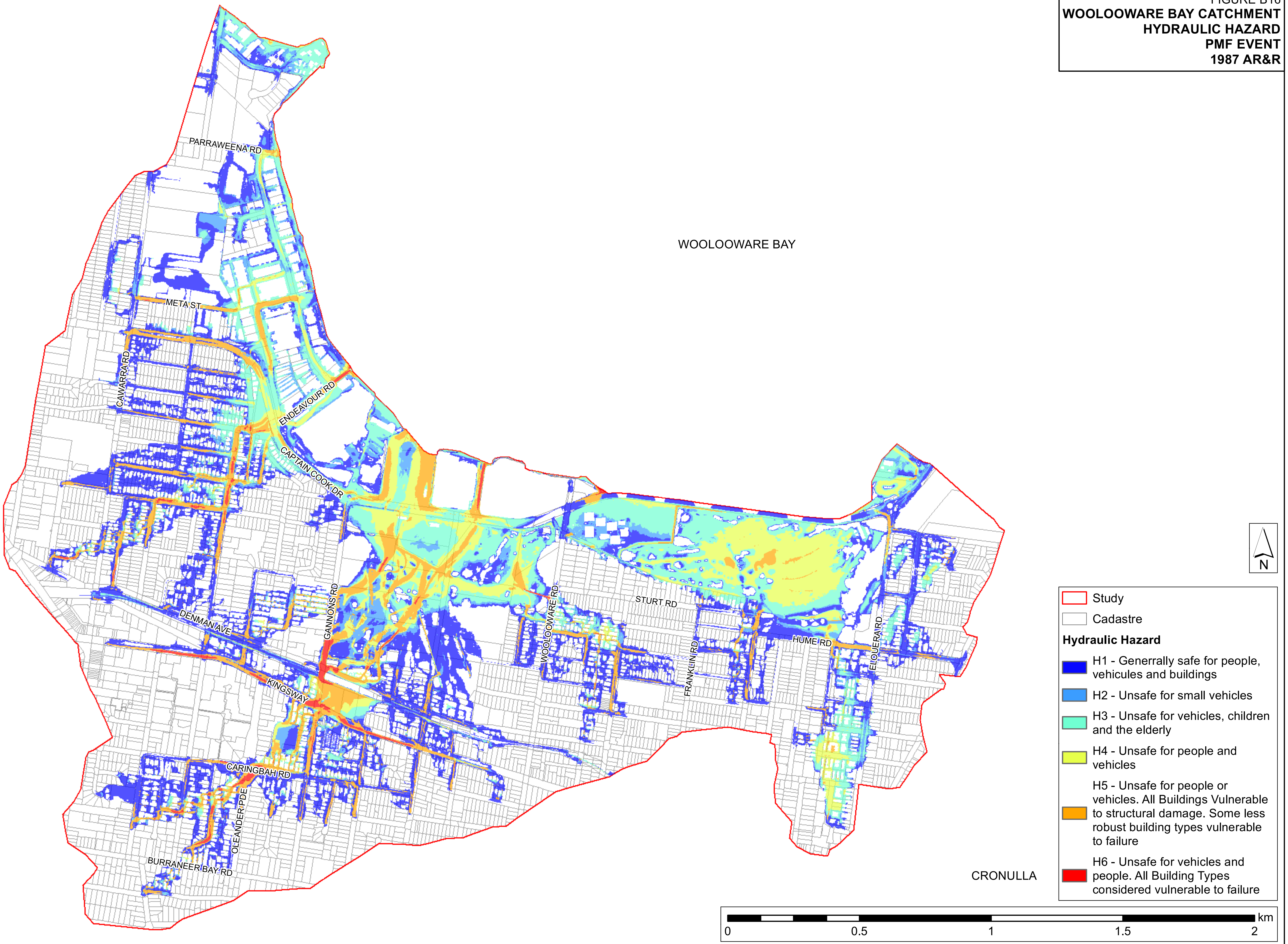
J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB15 Hydraulic Hazard 0p2pcAEP Event 2019AR&R.mxd

FIGURE B16A
WOOLOOWARE BAY CATCHMENT
HYDRAULIC HAZARD
PMF EVENT
1987 AR&R



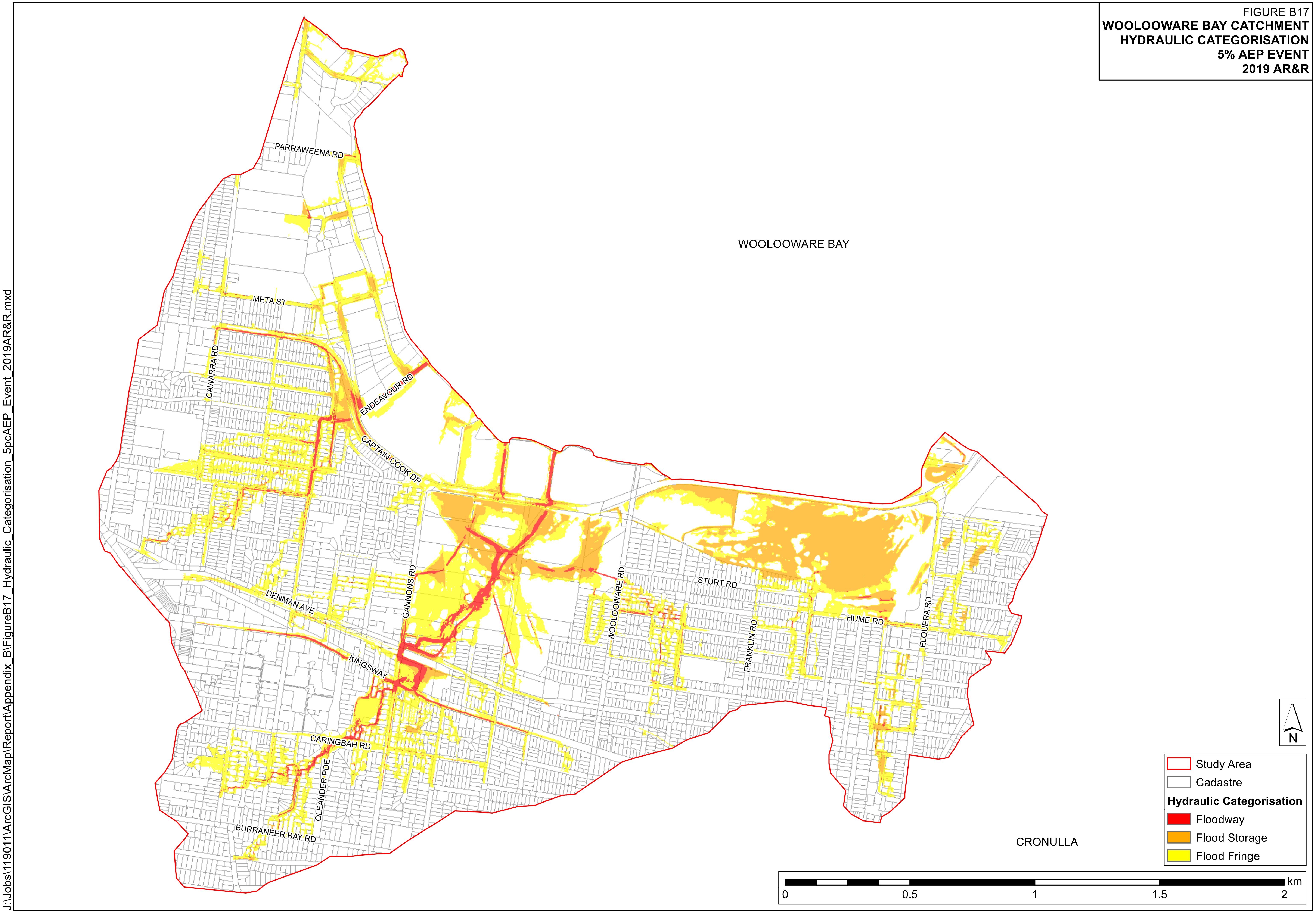
J:\Jobs\119011\ArcMap\Report\Appendix B\FigureB16A Hydraulic Hazard PMF Event 1987AR&R.mxd

FIGURE B16
WOOLOOWARE BAY CATCHMENT
HYDRAULIC HAZARD
PMF EVENT
1987 AR&R



J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB16_Hydraulic_Hazard_PMF_Event_1987AR&R.mxd

FIGURE B17
WOOLOOWARE BAY CATCHMENT
HYDRAULIC CATEGORISATION
5% AEP EVENT
2019 AR&R



J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB17_Hydraulic_Categorisation_5pcAEP_Event_2019AR&R.mxd

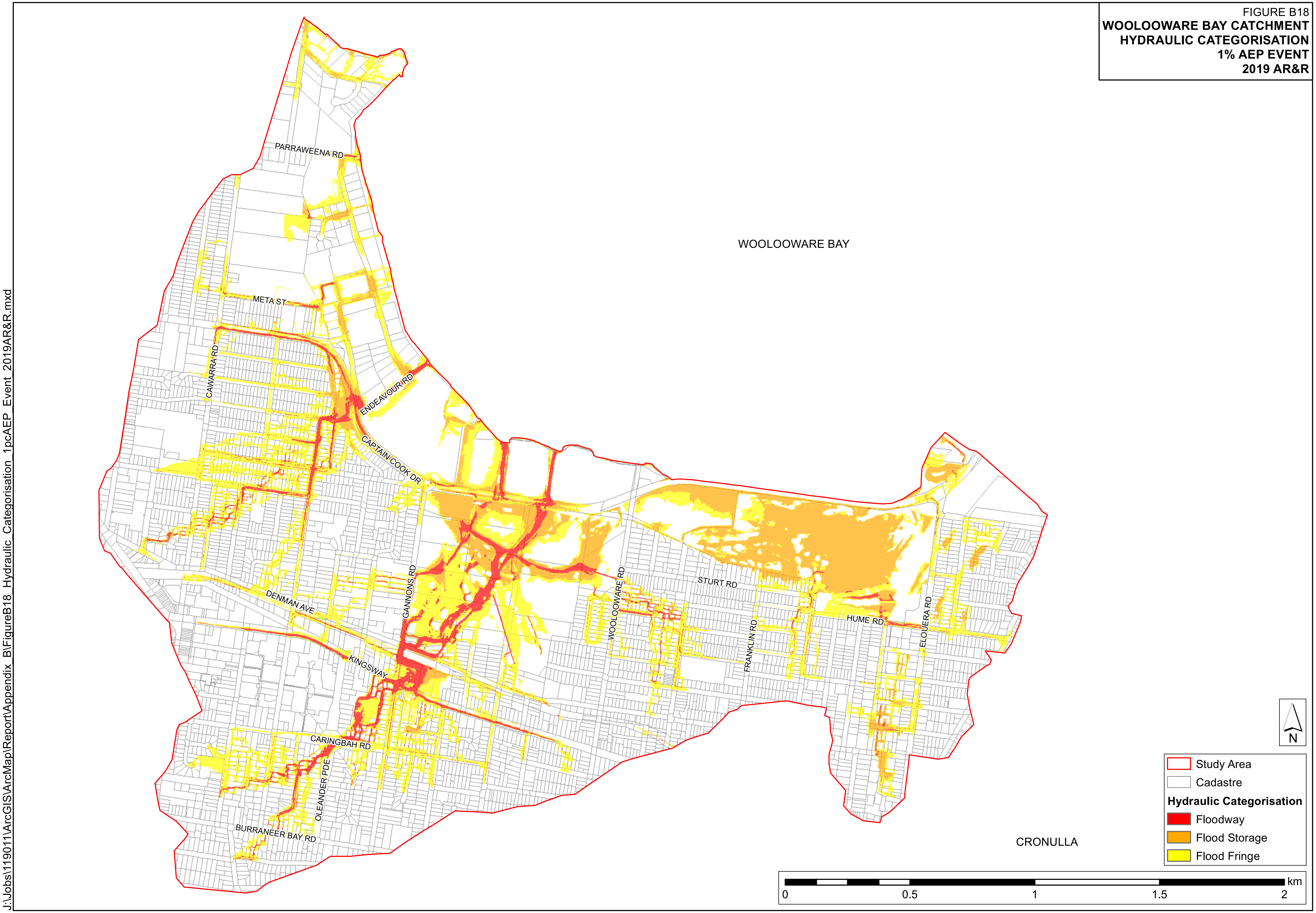
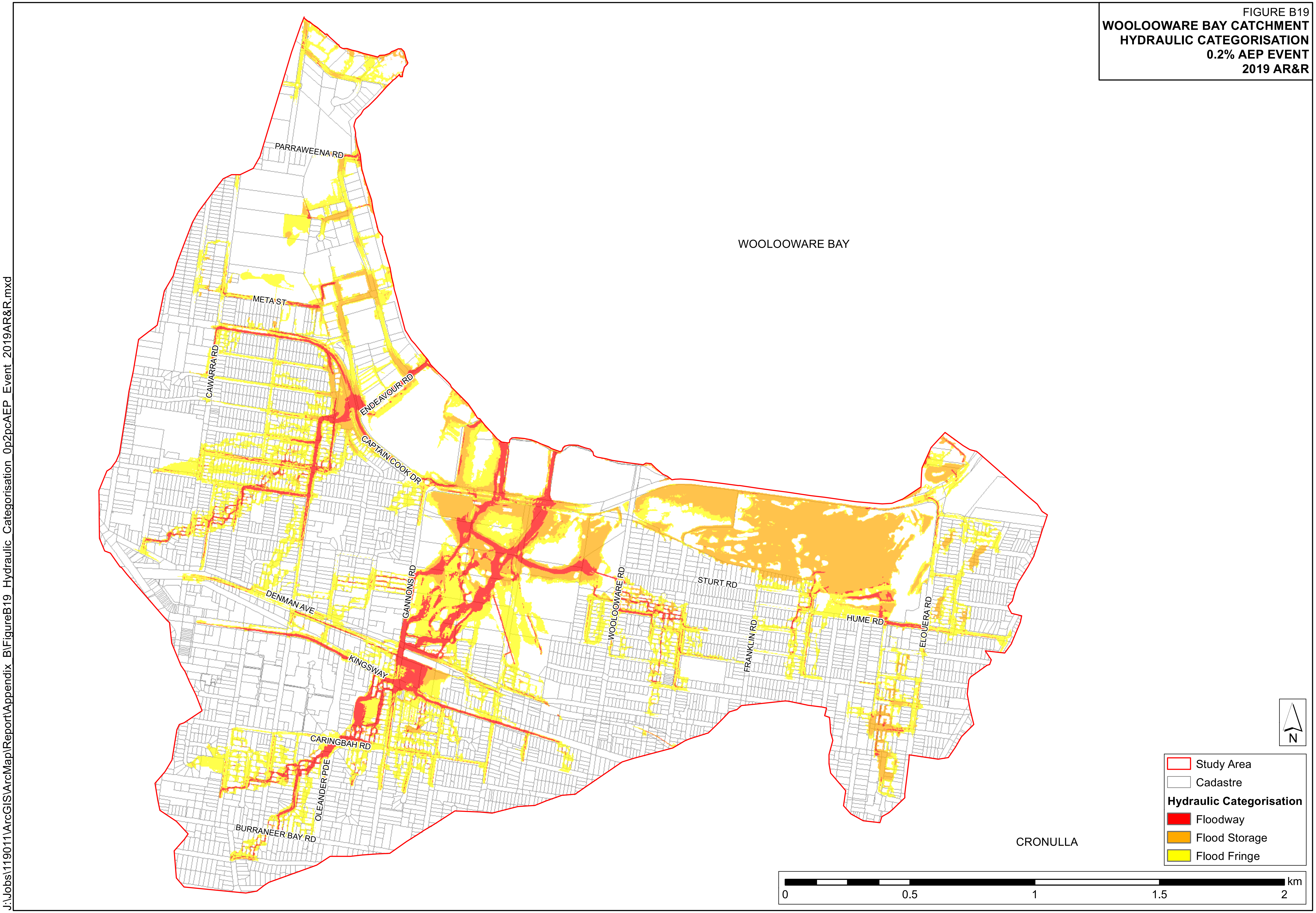
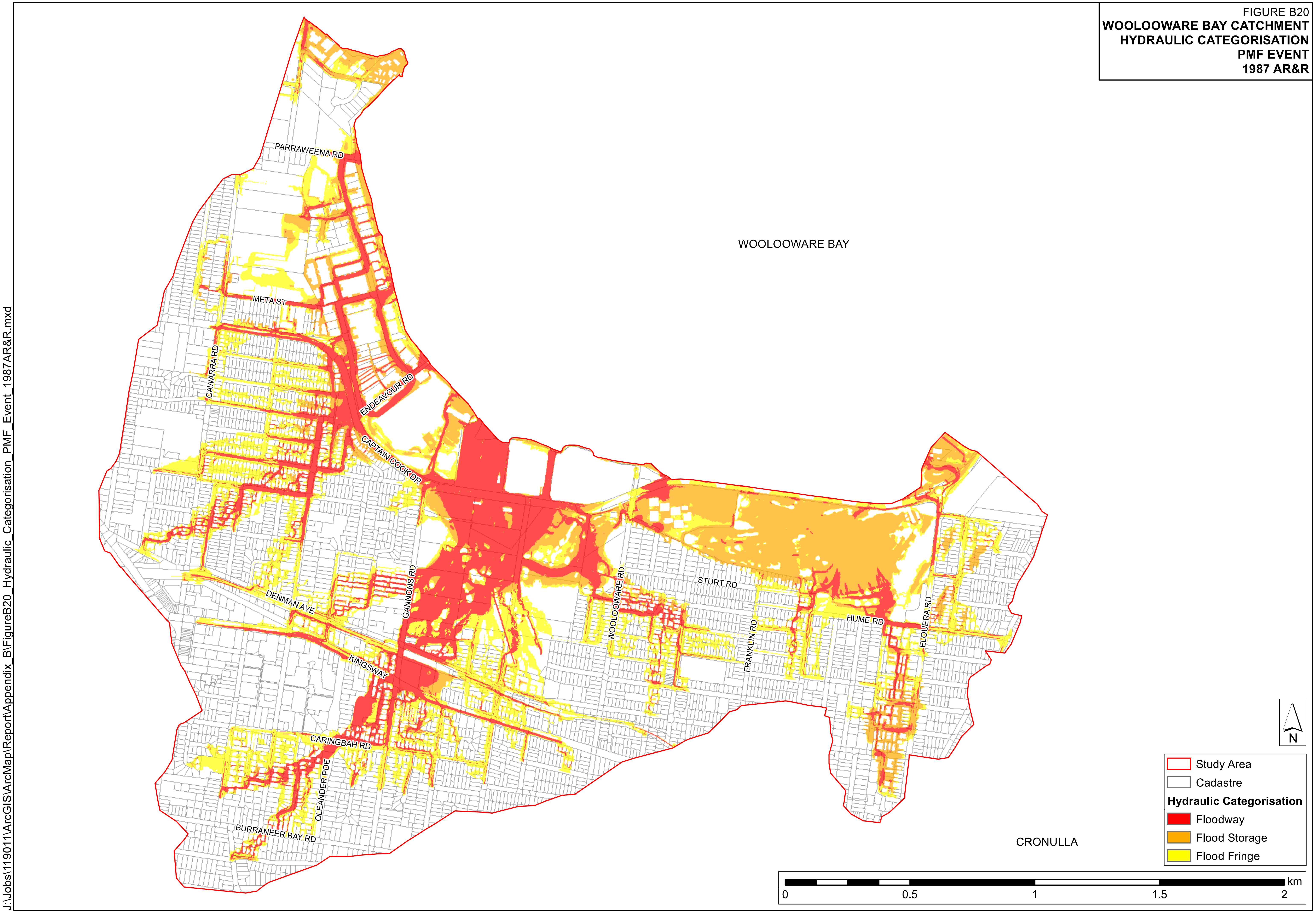


FIGURE B18
WOOLOOWARE BAY CATCHMENT
HYDRAULIC CATEGORISATION
1% AEP EVENT
2019 AR&R
WOOLOOWARE BAY
PARRAWEENA RD
META ST
CAWARRA RD
ENDEAVOUR RD
CAPTAIN COOK DR
GANNONS RD
DENMAN AVE
KINGSWAY
CARINGBAH RD
OLEANDER PDE
BURRANEER BAY RD
WOOLOOWARE RD
STURT RD
FRANKLIN RD
HUME RD
ELOUERA RD
CRONULLA
N
Study Area
Cadastre
Hydraulic Categorisation
Floodway
Flood Storage
Flood Fringe
km
0
0.5
1
1.5
2
J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB18_Hydraulic_Categorisation_1pcAEP_Event_2019AR&R.mxd

FIGURE B19
WOOLOOWARE BAY CATCHMENT
HYDRAULIC CATEGORISATION
0.2% AEP EVENT
2019 AR&R

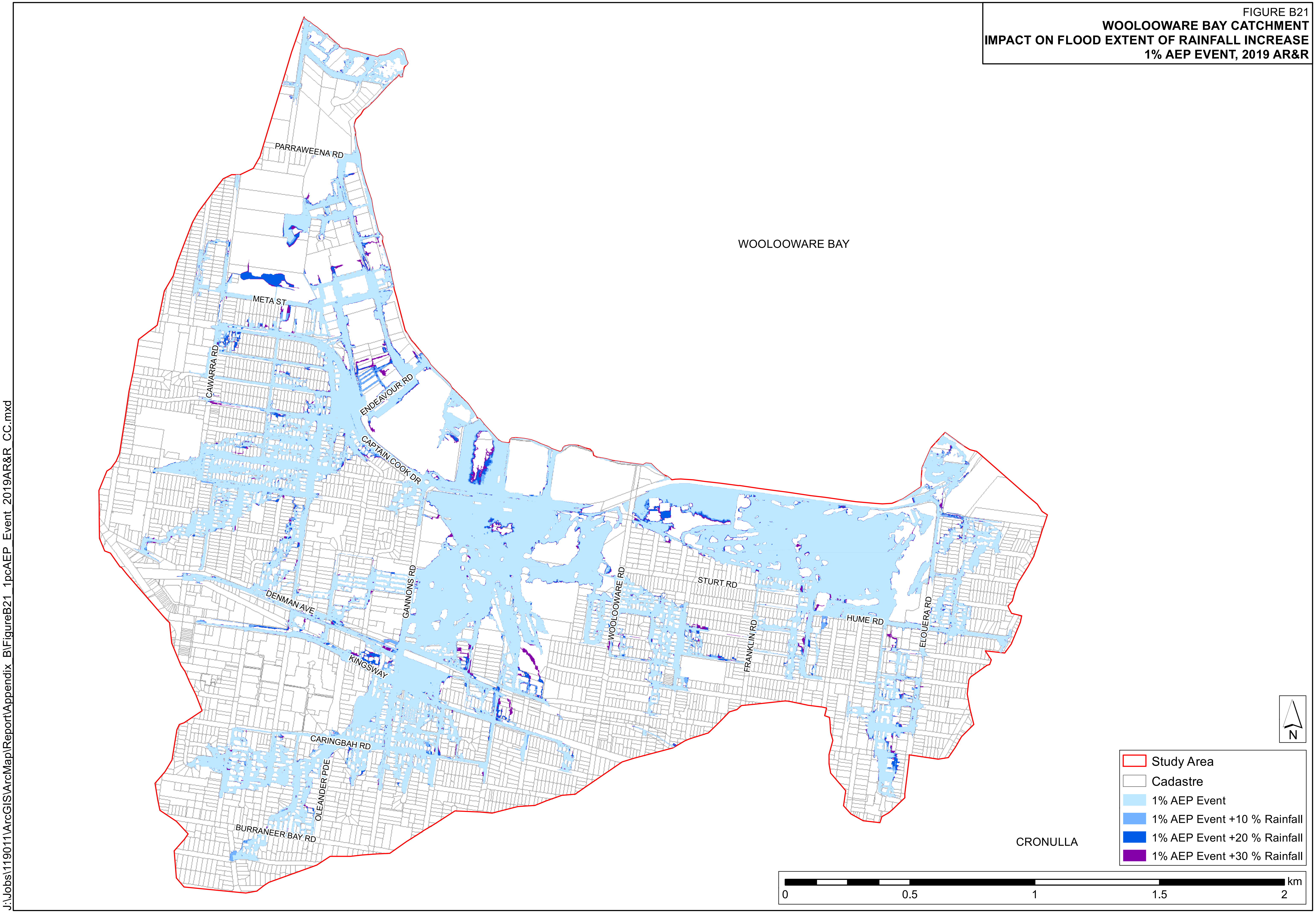


J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB19_Hydraulic_Categorisation_0p2pcAEP_Event_2019AR&R.mxd



J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB20 Hydraulic Categorisation PMF Event 1987AR&R.mxd

FIGURE B21
WOOLOOWARE BAY CATCHMENT
IMPACT ON FLOOD EXTENT OF RAINFALL INCREASE
1% AEP EVENT, 2019 AR&R



J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB21_1pcAEP_Event_2019AR&R_CC.mxd

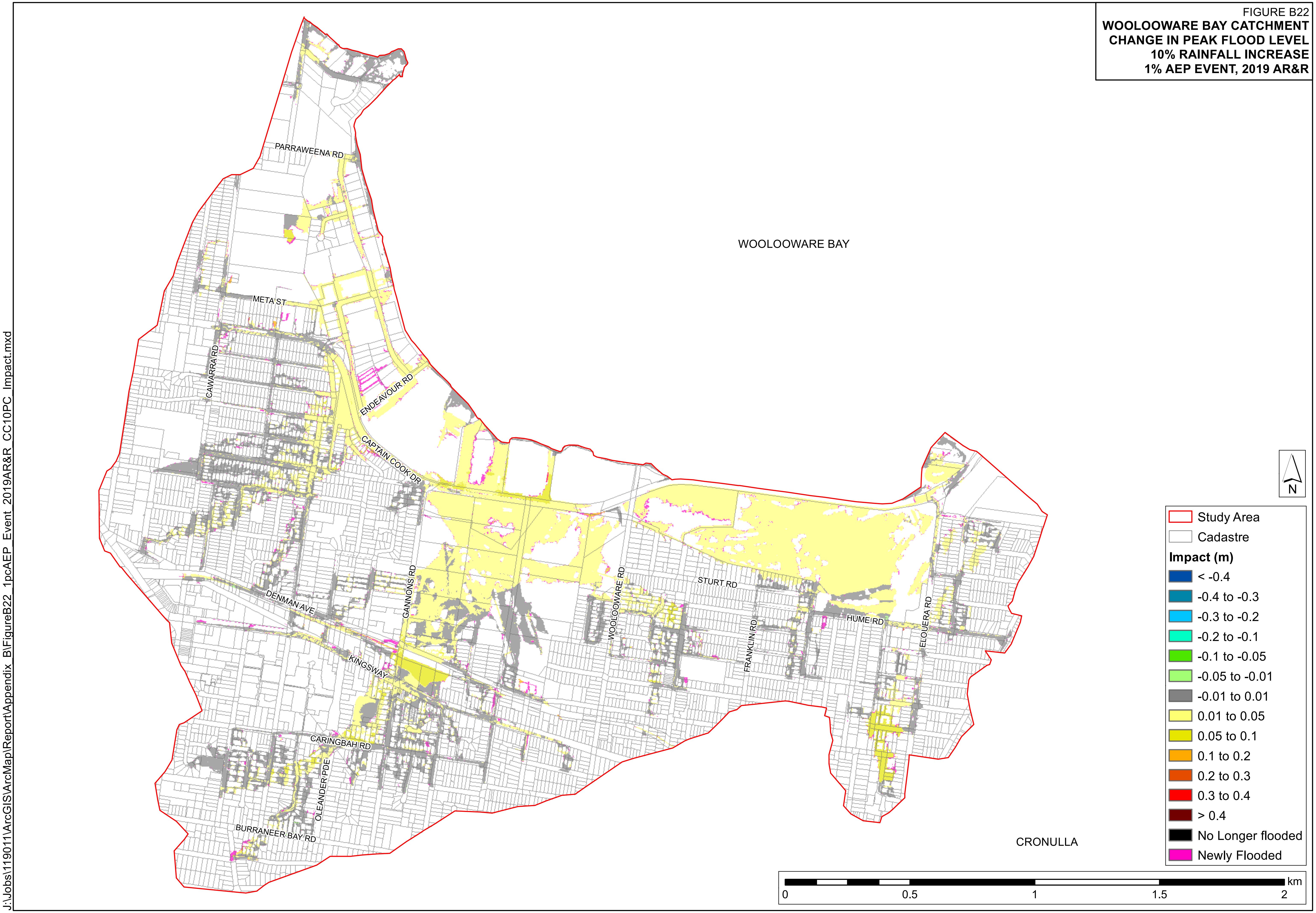
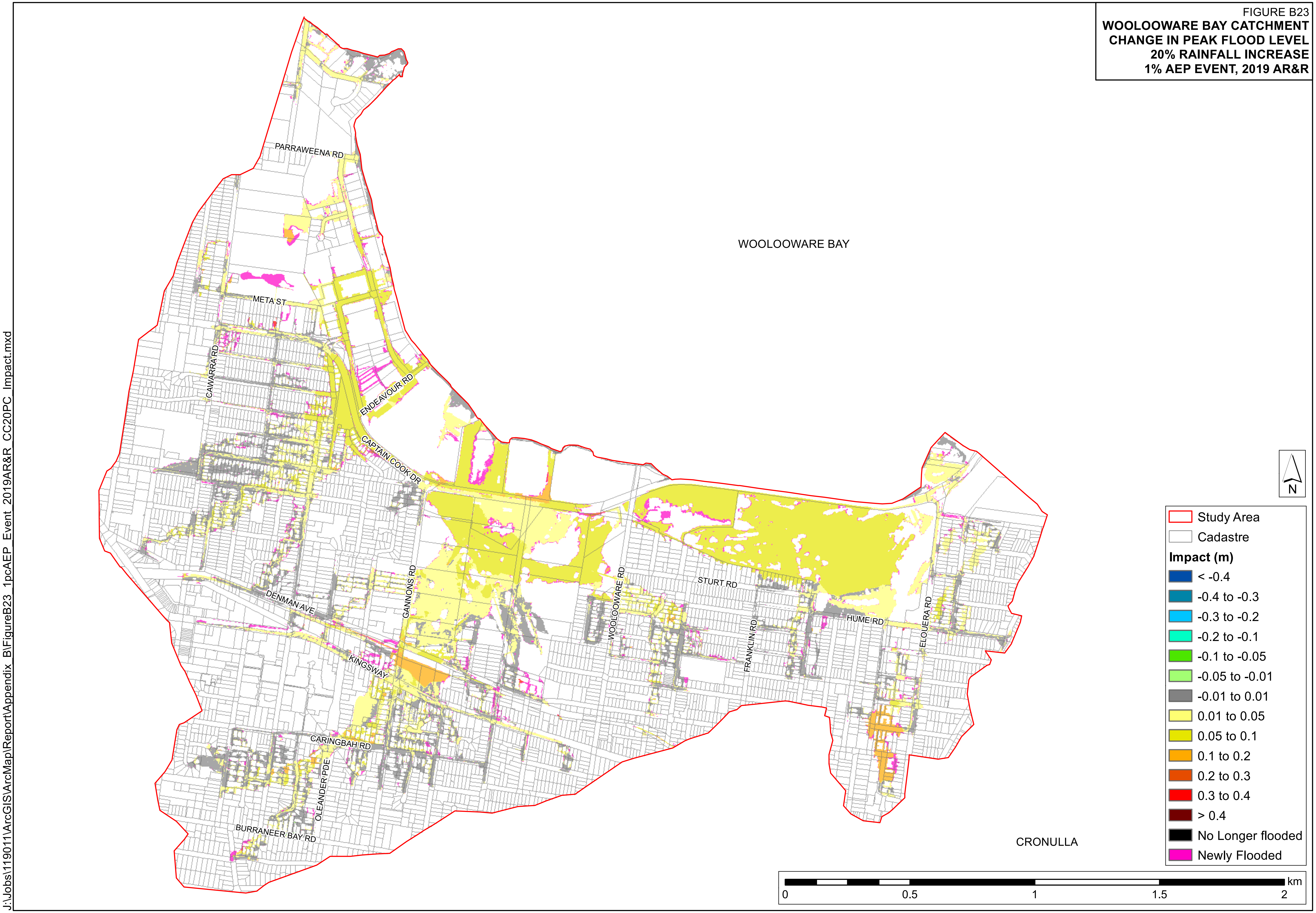


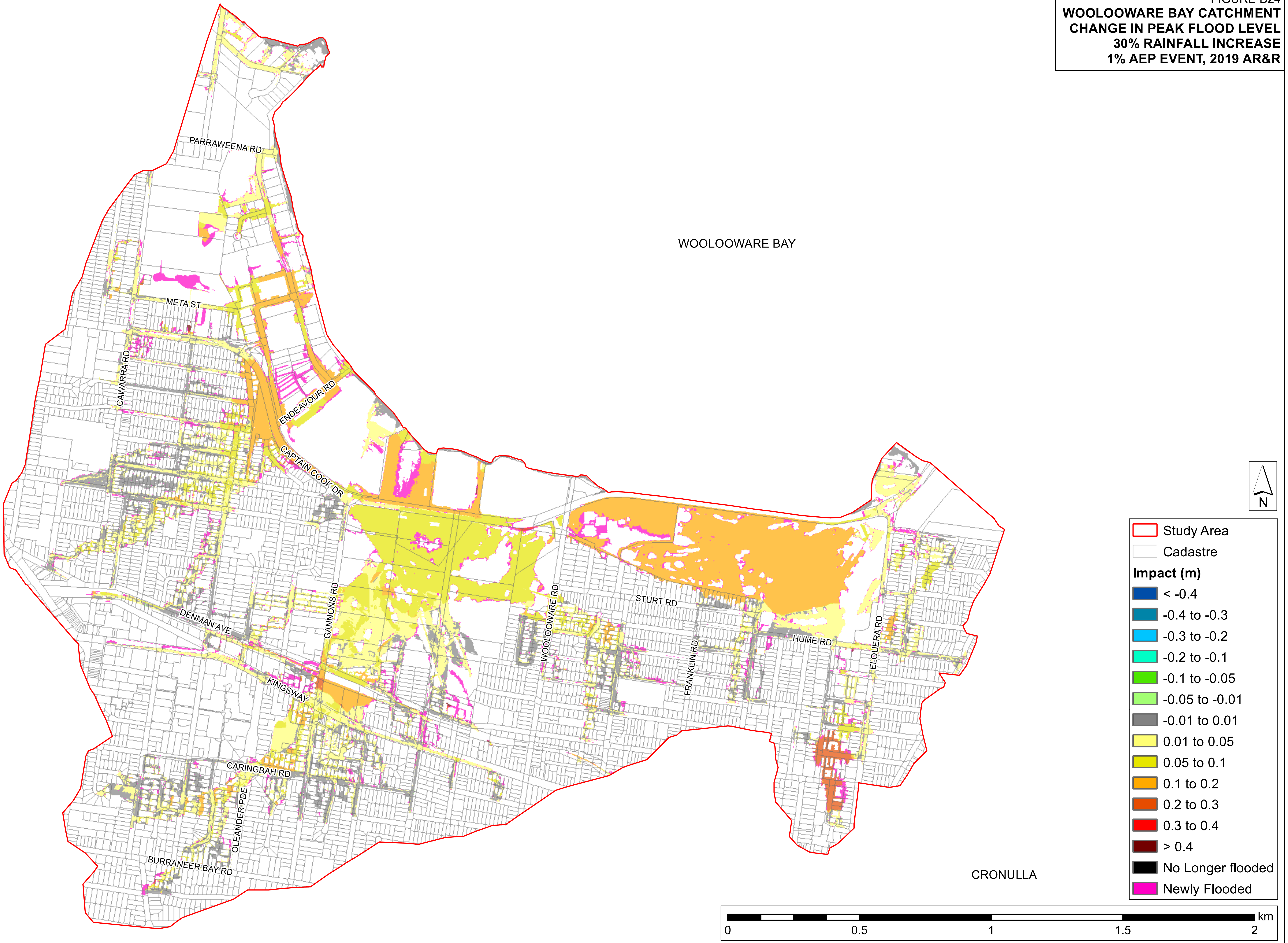
FIGURE B22
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
10% RAINFALL INCREASE
1% AEP EVENT, 2019 AR&R
WOOLOOWARE BAY
PARRAWEENA RD
META ST
CAWARRA RD
ENDEAVOUR RD
CAPTAIN COOK DR
DENMAN AVE
GANNONS RD
KINGSWAY
CARINGBAH RD
OLEANDER PDE
BURRANEER BAY RD
WOOLOOWARE RD
STURT RD
FRANKLIN RD
HUME RD
ELOUERA RD
CRONULLA
N
Study Area
Cadastre
Impact (m)
< -0.4
-0.4 to -0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
0.3 to 0.4
> 0.4
No Longer flooded
Newly Flooded
0
0.5
1
1.5
2
km
J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix_B\FigureB22_1pcAEP_Event_2019AR&R_CC10PC_Impact.mxd

FIGURE B23
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
20% RAINFALL INCREASE
1% AEP EVENT, 2019 AR&R



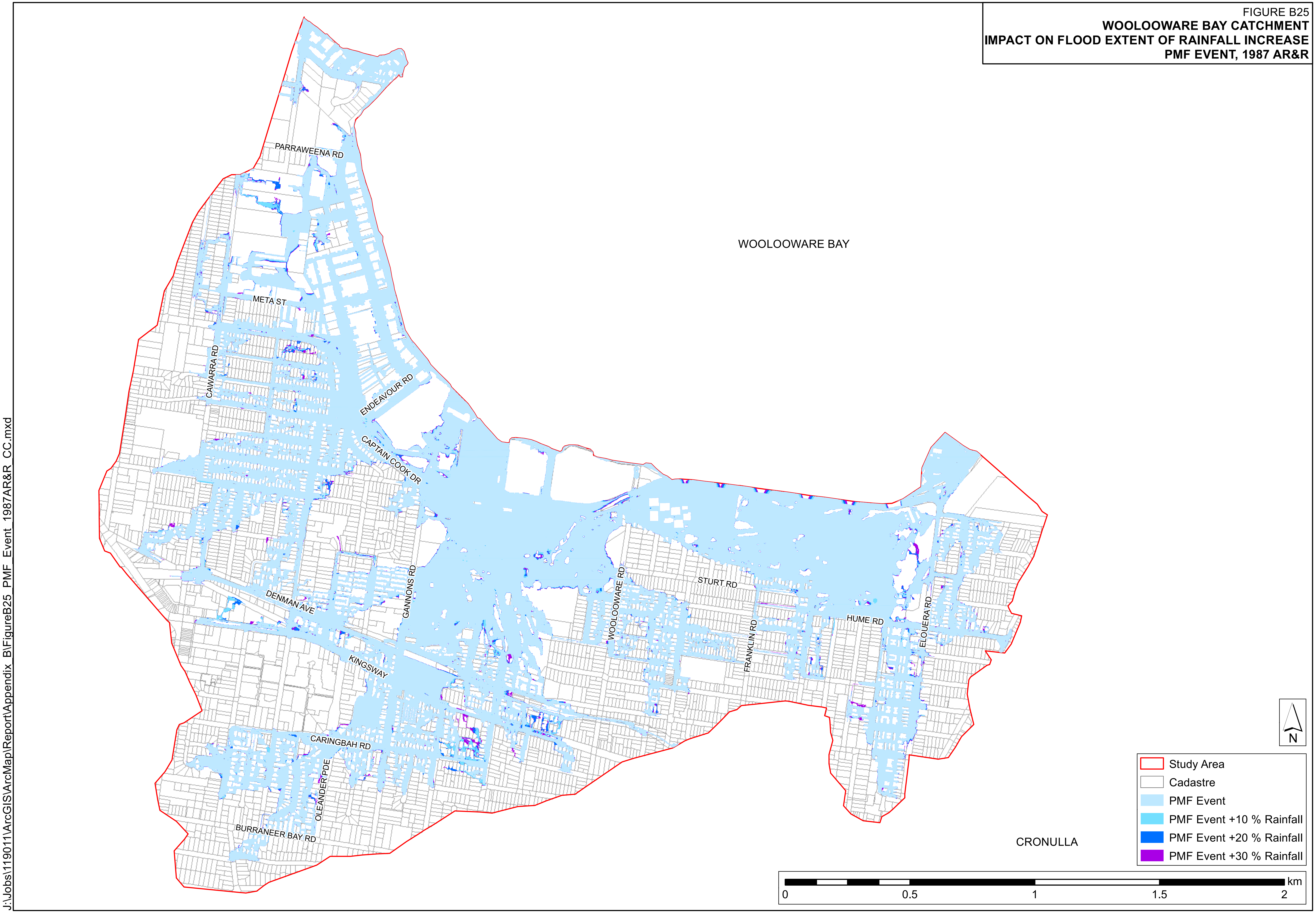
J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB23_1pcAEP_Event_2019AR&R_CC20PC_Impact.mxd

FIGURE B24
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
30% RAINFALL INCREASE
1% AEP EVENT, 2019 AR&R



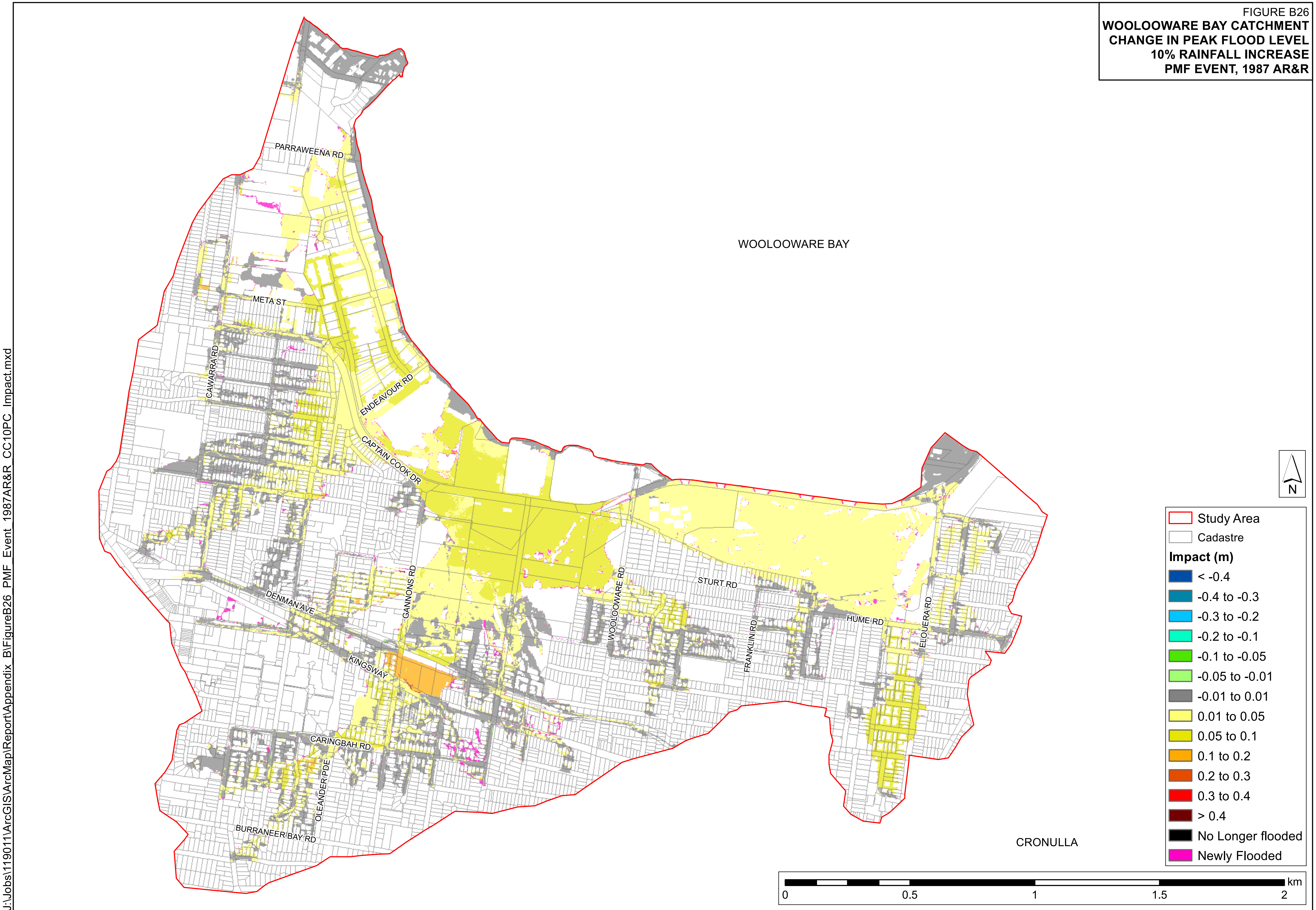
J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB24_1pcAEP_Event_2019AR&R_CC30PC_Impact.mxd

FIGURE B25
WOOLOOWARE BAY CATCHMENT
IMPACT ON FLOOD EXTENT OF RAINFALL INCREASE
PMF EVENT, 1987 AR&R



J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB25_PMF_Event_1987AR&R_CC.mxd

FIGURE B26
WOOLOOWARE BAY CATCHMENT CHANGE IN PEAK FLOOD LEVEL 10% RAINFALL INCREASE PMF EVENT, 1987 AR&R



J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB26_PMF_Event_1987AR&R_CC10PC_Impact.mxd

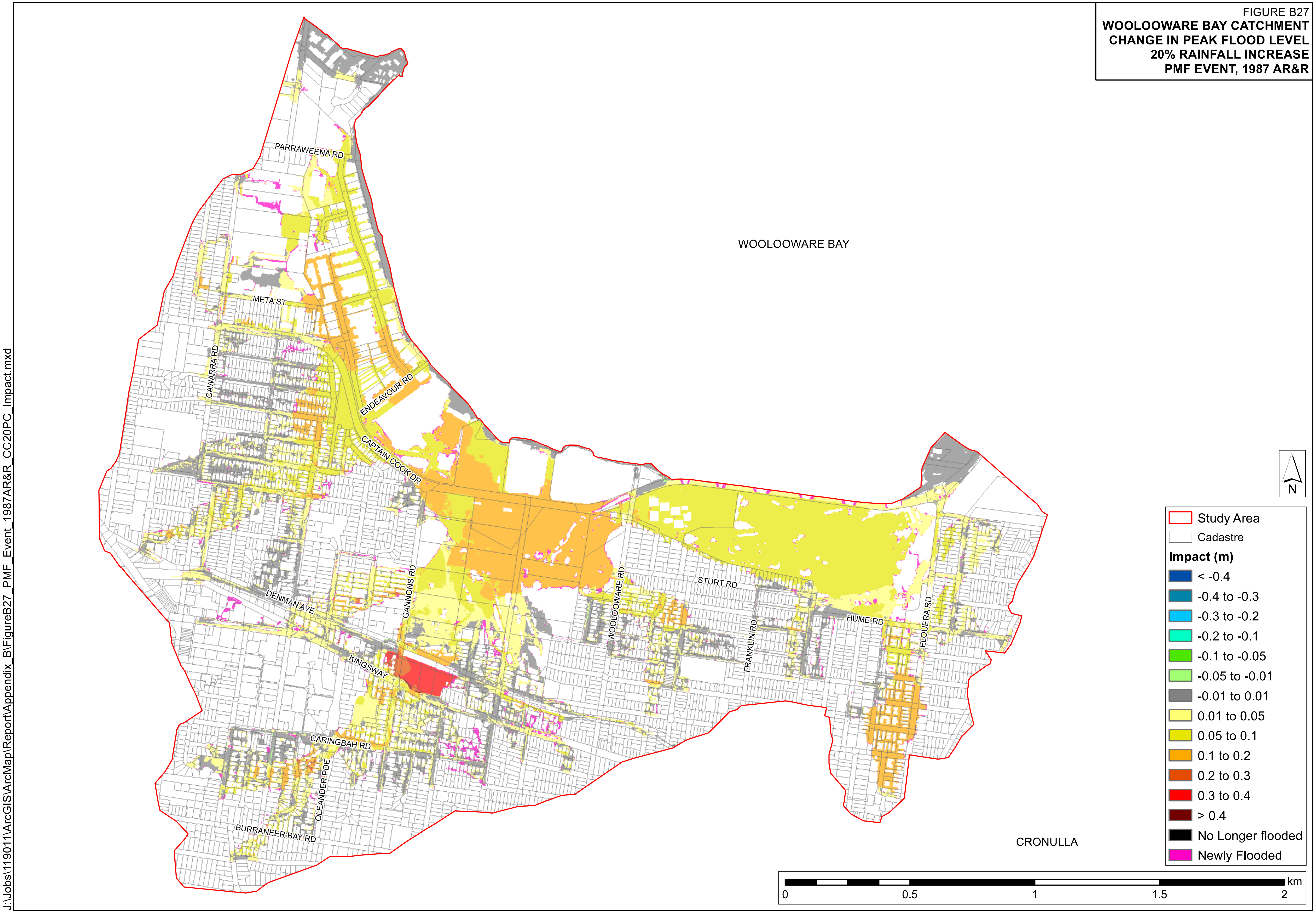


FIGURE B27
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
20% RAINFALL INCREASE
PMF EVENT, 1987 AR&R
WOOLOOWARE BAY
PARRAWEENA RD
META ST
CAWARRA RD
ENDEAVOUR RD
CAPTAIN COOK DR
DENMAN AVE
GANNONS RD
KINGSWAY
CARINGBAH RD
OLEANDER PDE
BURRANEER BAY RD
WOOLOOWARE RD
STURT RD
FRANKLIN RD
HUME RD
ELOUERA RD
CRONULLA
N
Study Area
Cadastre
Impact (m)
< -0.4
-0.4 to -0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
0.3 to 0.4
> 0.4
No Longer flooded
Newly Flooded
0
0.5
1
1.5
2
km
J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB27_PMF_Event_1987AR&R_CC20PC_Impact.mxd

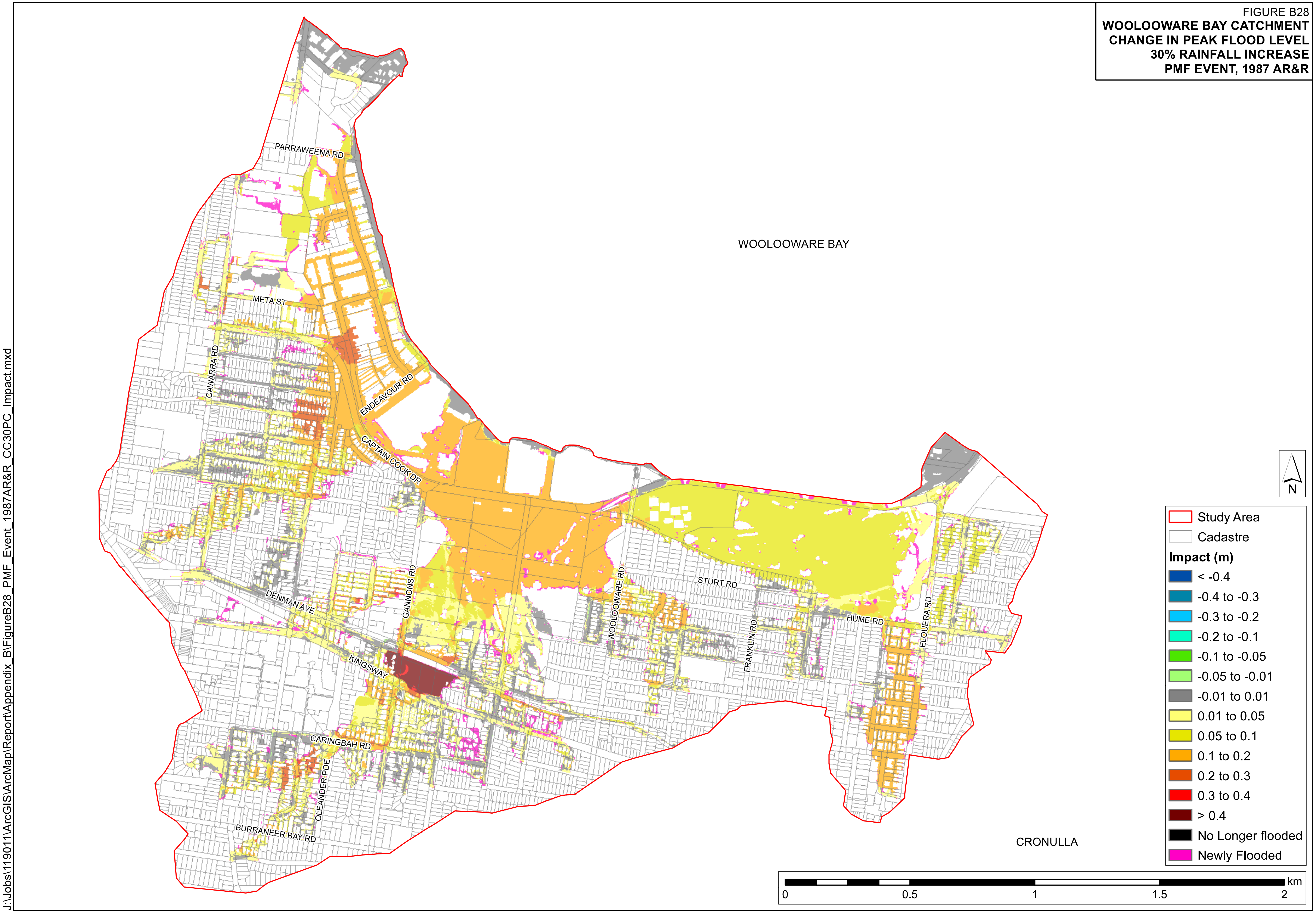
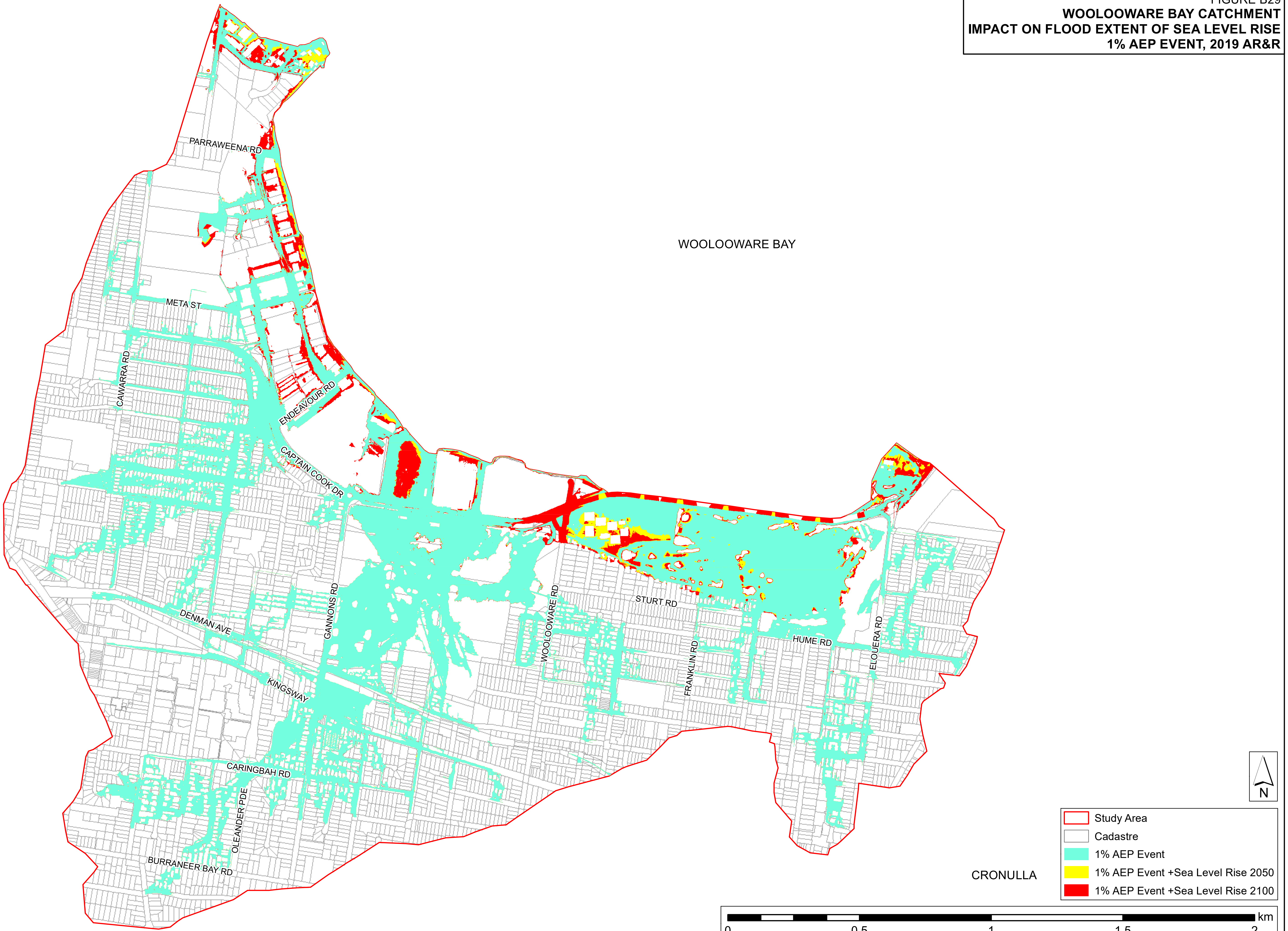


FIGURE B28
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
30% RAINFALL INCREASE
PMF EVENT, 1987 AR&R
WOOLOOWARE BAY
PARRAWEENA RD
META ST
CAWARRA RD
ENDEAVOUR RD
CAPTAIN COOK DR
DENMAN AVE
GANNONS RD
KINGSWAY
CARINGBAH RD
OLEANDER PDE
BURRANEER BAY RD
WOOLOOWARE RD
STURT RD
FRANKLIN RD
HUME RD
ELOUERA RD
CRONULLA
N
Study Area
Cadastre
Impact (m)
< -0.4
-0.4 to -0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
0.3 to 0.4
> 0.4
No Longer flooded
Newly Flooded
km
0
0.5
1
1.5
2
J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB28_PMF_Event_1987AR&R_CC30PC_Impact.mxd

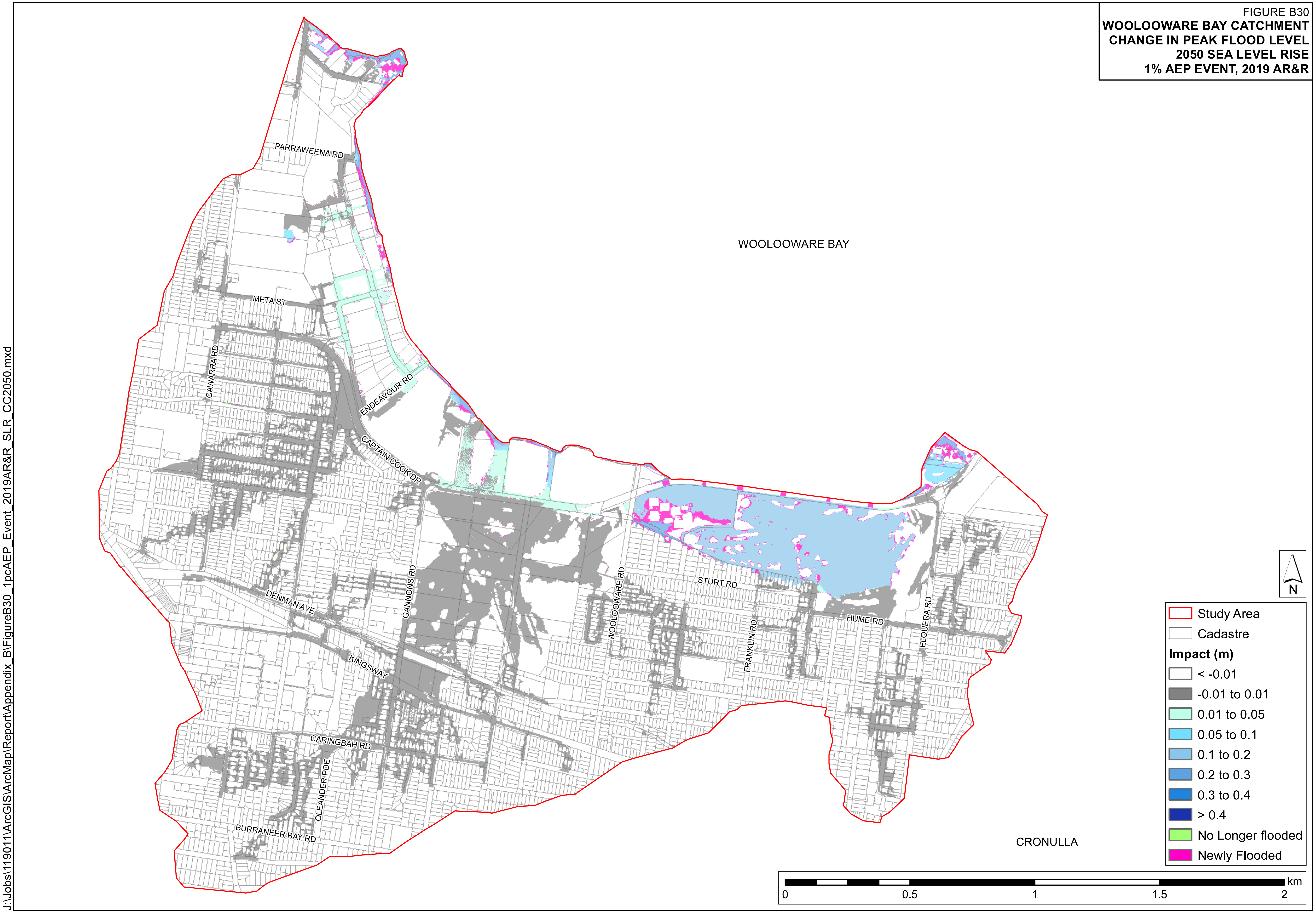
FIGURE B29

WOOLOOWARE BAY CATCHMENT
IMPACT ON FLOOD EXTENT OF SEA LEVEL RISE
1% AEP EVENT, 2019 AR&R



J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB29_1pcAEP_Event_2019AR&R_SLR_CC.mxd

FIGURE B30
WOOLOOWARE BAY CATCHMENT CHANGE IN PEAK FLOOD LEVEL 2050 SEA LEVEL RISE 1% AEP EVENT, 2019 AR&R



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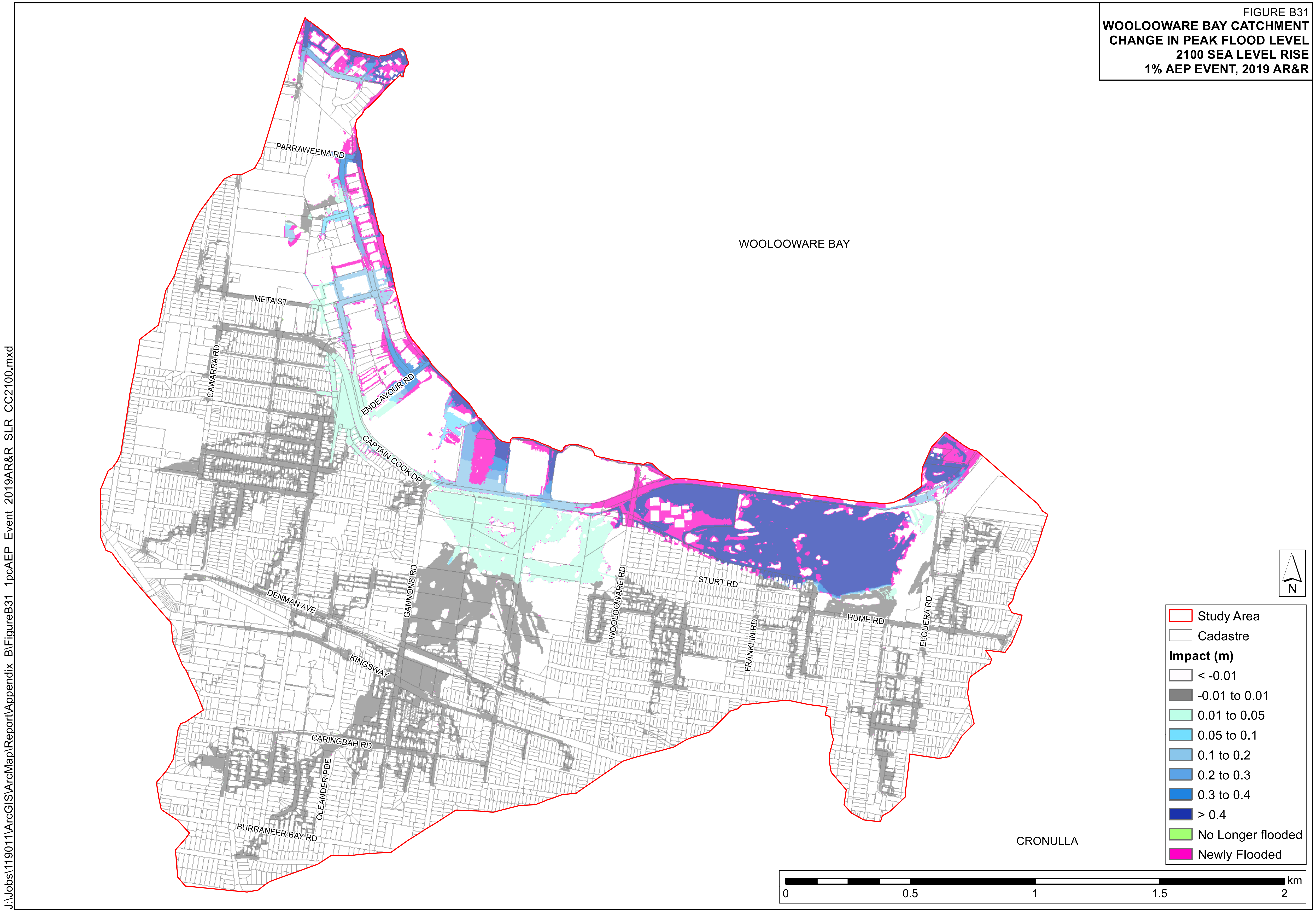
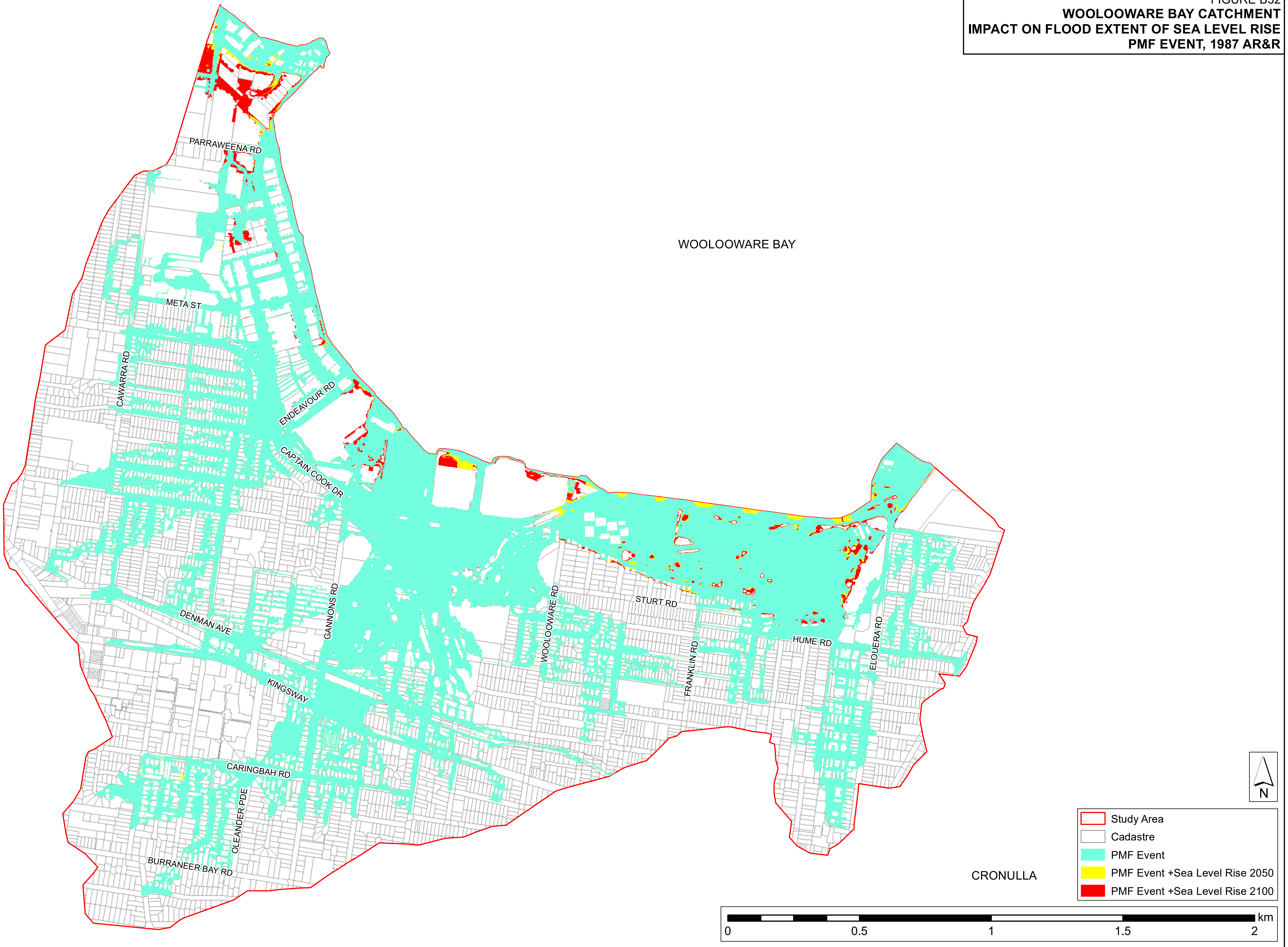


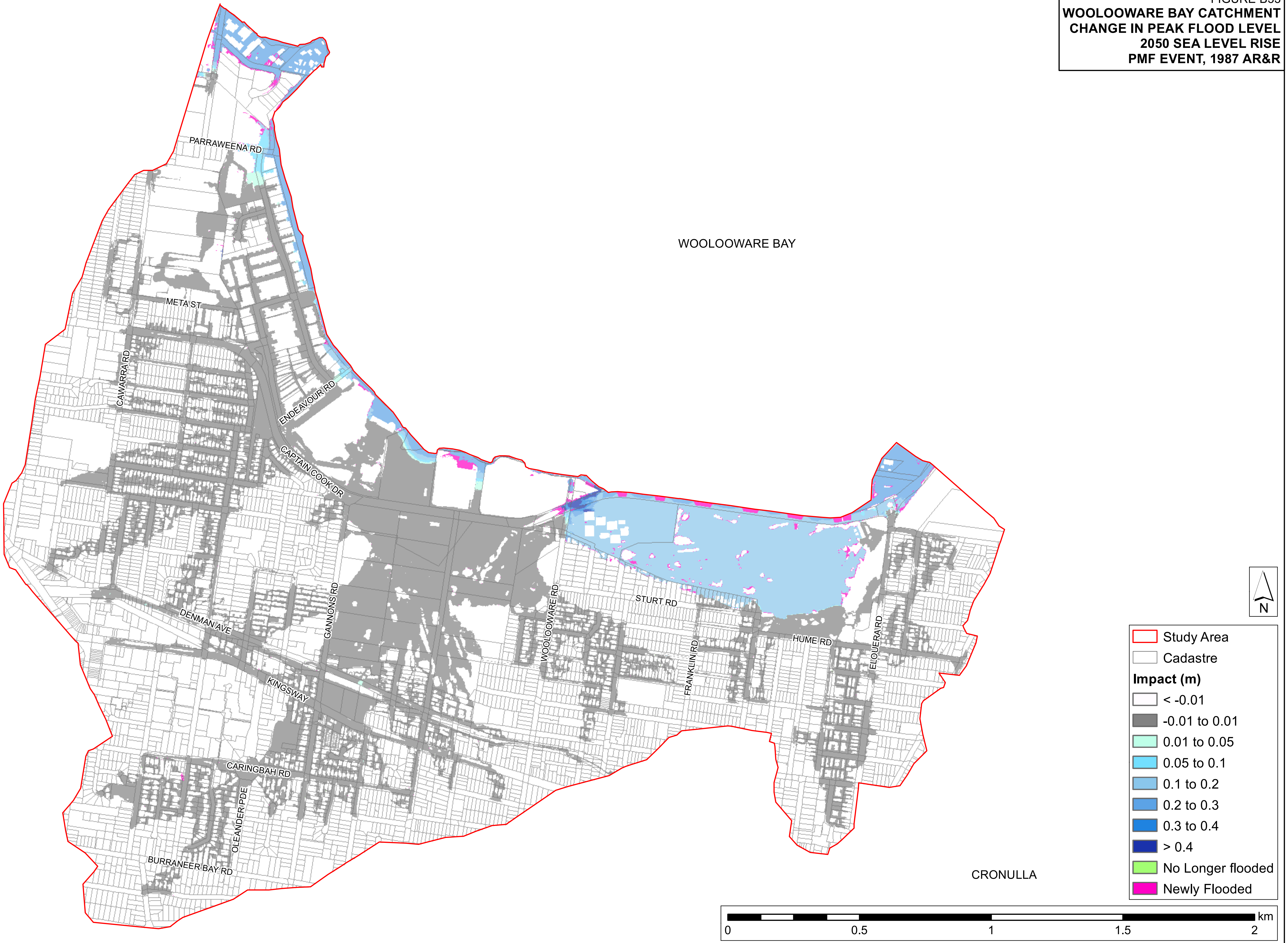
FIGURE B31
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
2100 SEA LEVEL RISE
1% AEP EVENT, 2019 AR&R
WOOLOOWARE BAY
PARRAWEENA RD
META ST
CAWARRA RD
ENDEAVOUR RD
CAPTAIN COOK DR
GANNONS RD
DENMAN AVE
KINGSWAY
WOOLOOWARE RD
STURT RD
FRANKLIN RD
HUME RD
ELOUERA RD
CARINGBAH RD
OLEANDER PDE
BURRANEER BAY RD
CRONULLA
N
Study Area
Cadastre
Impact (m)
< -0.01
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
0.3 to 0.4
> 0.4
No Longer flooded
Newly Flooded
0
0.5
1
1.5
2
km
J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB31_1pcAEP_Event_2019AR&R_SLR_CC2100.mxd

FIGURE B32
WOOLOOWARE BAY CATCHMENT
IMPACT ON FLOOD EXTENT OF SEA LEVEL RISE
PMF EVENT, 1987 AR&R



J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB32_PMF_Event_1987AR&R_SLR_CC.mxd

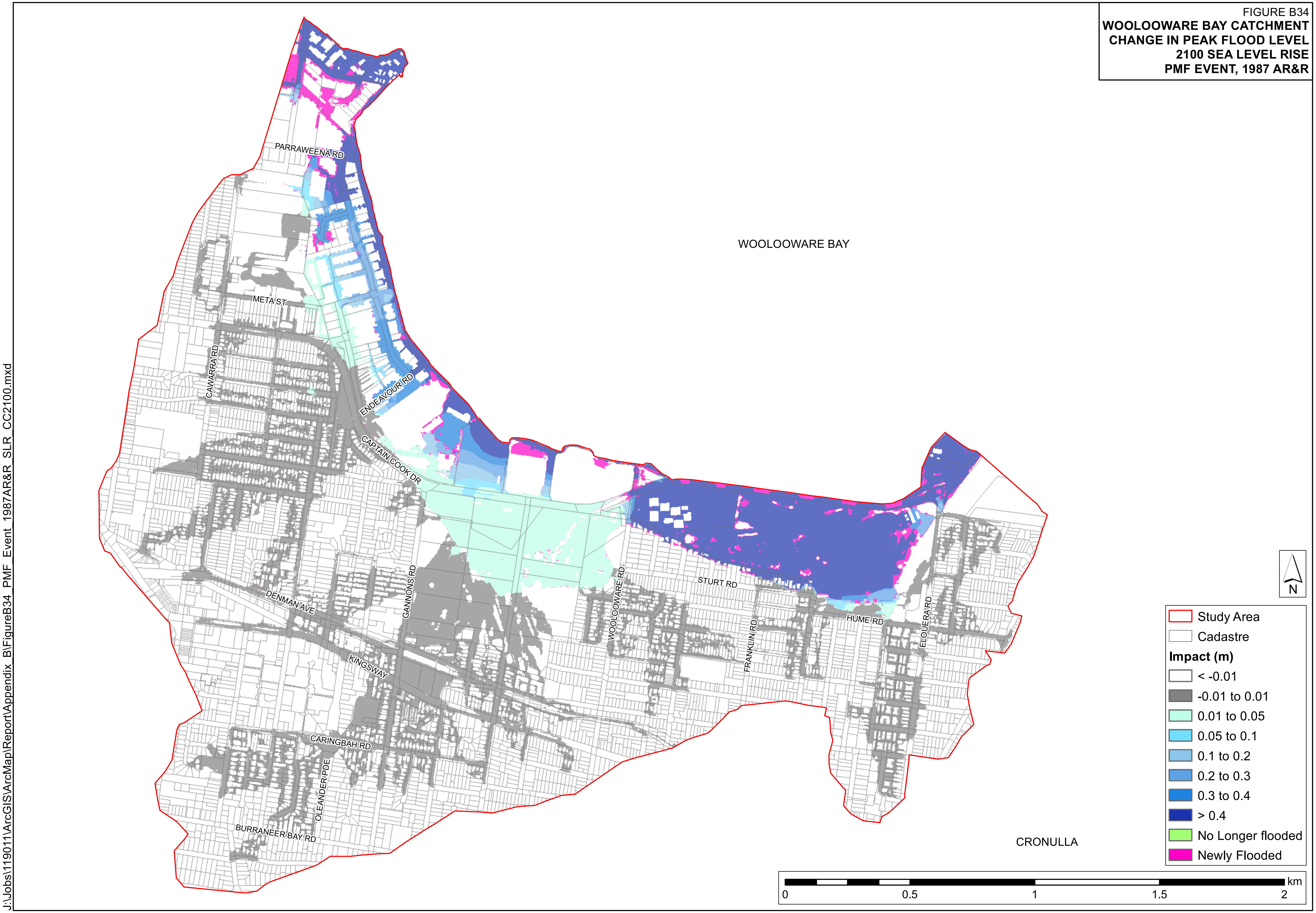
FIGURE B33
WOOLOOWARE BAY CATCHMENT CHANGE IN PEAK FLOOD LEVEL 2050 SEA LEVEL RISE PMF EVENT, 1987 AR&R



J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB33_PMF_Event_1987AR&R_SLR_CC2050.mxd

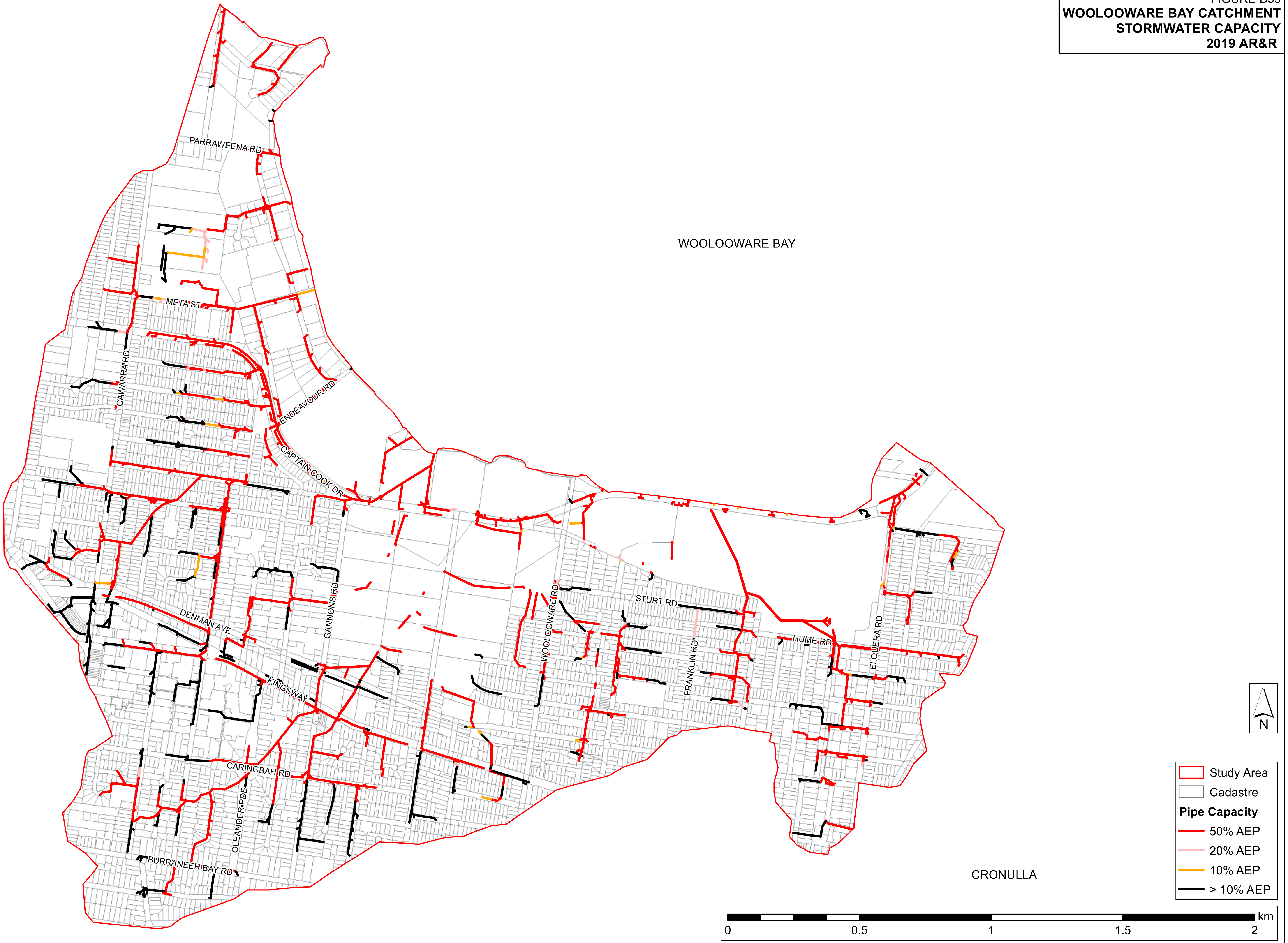
FIGURE B34

WOOLOOWARE BAY CATCHMENT CHANGE IN PEAK FLOOD LEVEL 2100 SEA LEVEL RISE PMF EVENT, 1987 AR&R



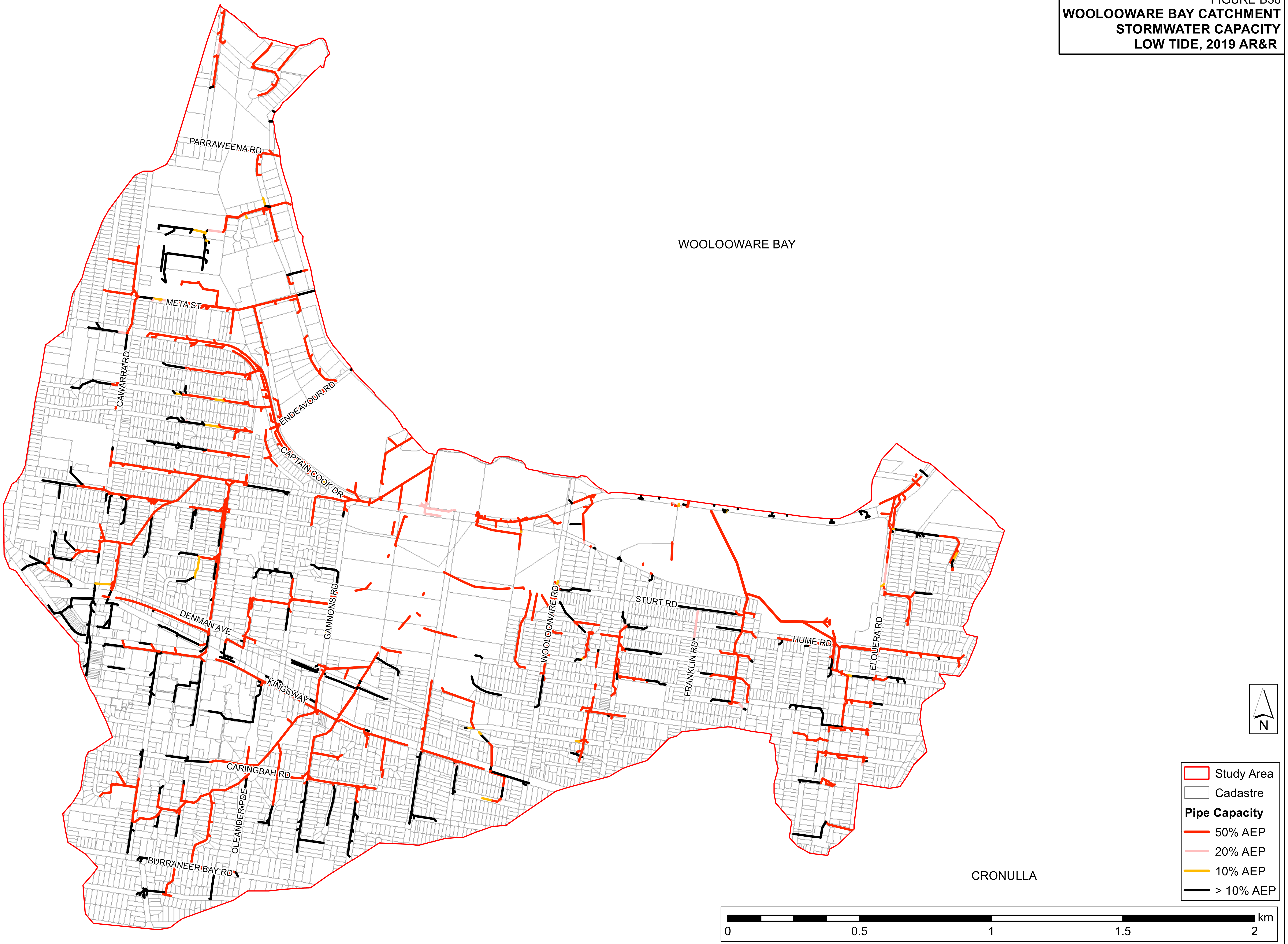
J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB34 PMF Event 1987AR&R SLR CC2100.mxd

FIGURE B35
WOOLOOWARE BAY CATCHMENT STORMWATER CAPACITY 2019 AR&R



J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB35_Stormwater_Capacity_2019AR&R.mxd

FIGURE B36
WOOLOOWARE BAY CATCHMENT STORMWATER CAPACITY LOW TIDE, 2019 AR&R



J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB36 Stormwater Capacity LowTide 2019AR&R.mxd

FIGURE B37
WOOLOOWARE BAY CATCHMENT
FLOOD EMERGENCY RESPONSE CLASSIFICATION

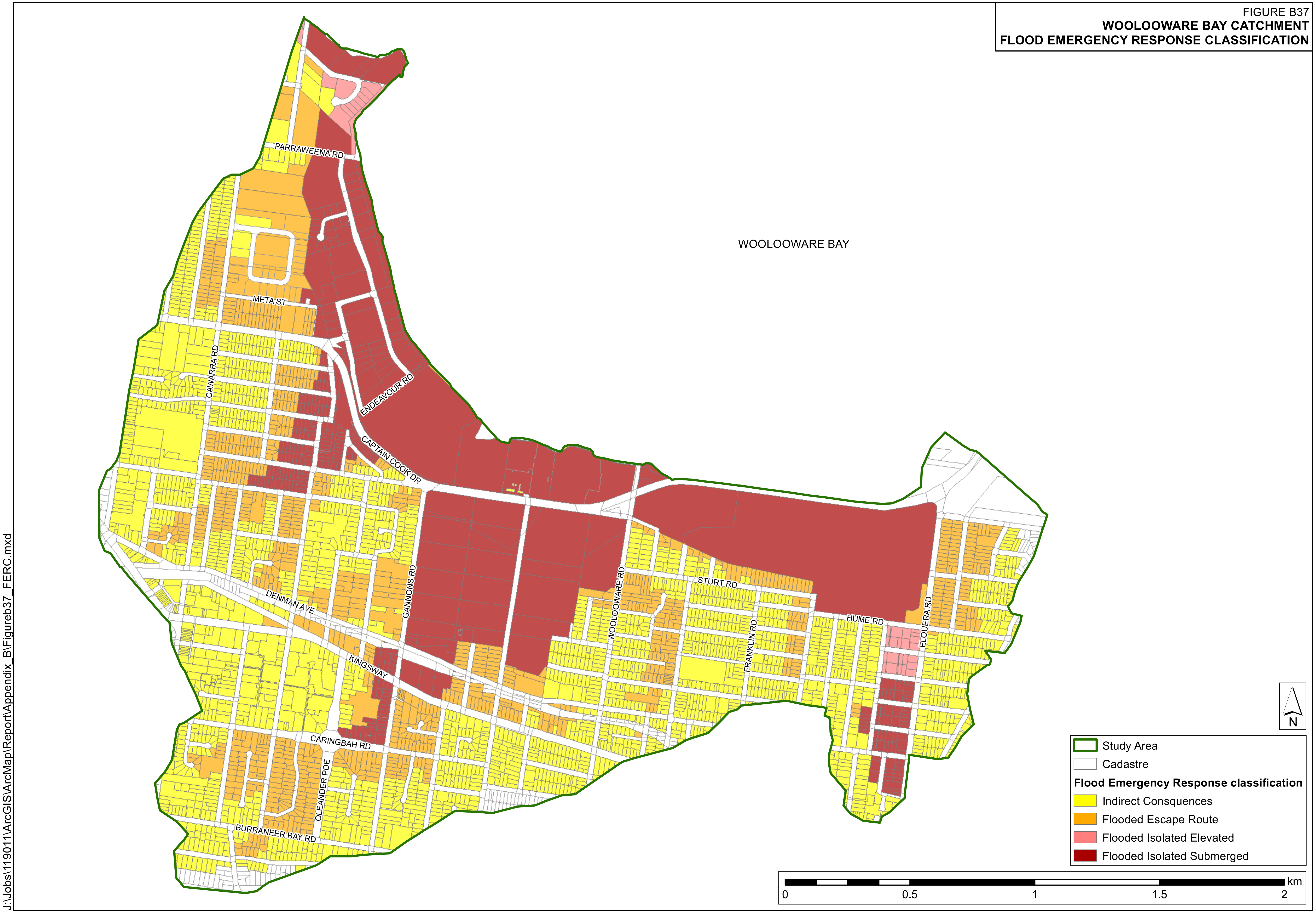


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FIGURE B38
WOOLOOWARE BAY CATCHMENT
FLOOD PLANNING CONSTRAINTS CATEGORIES

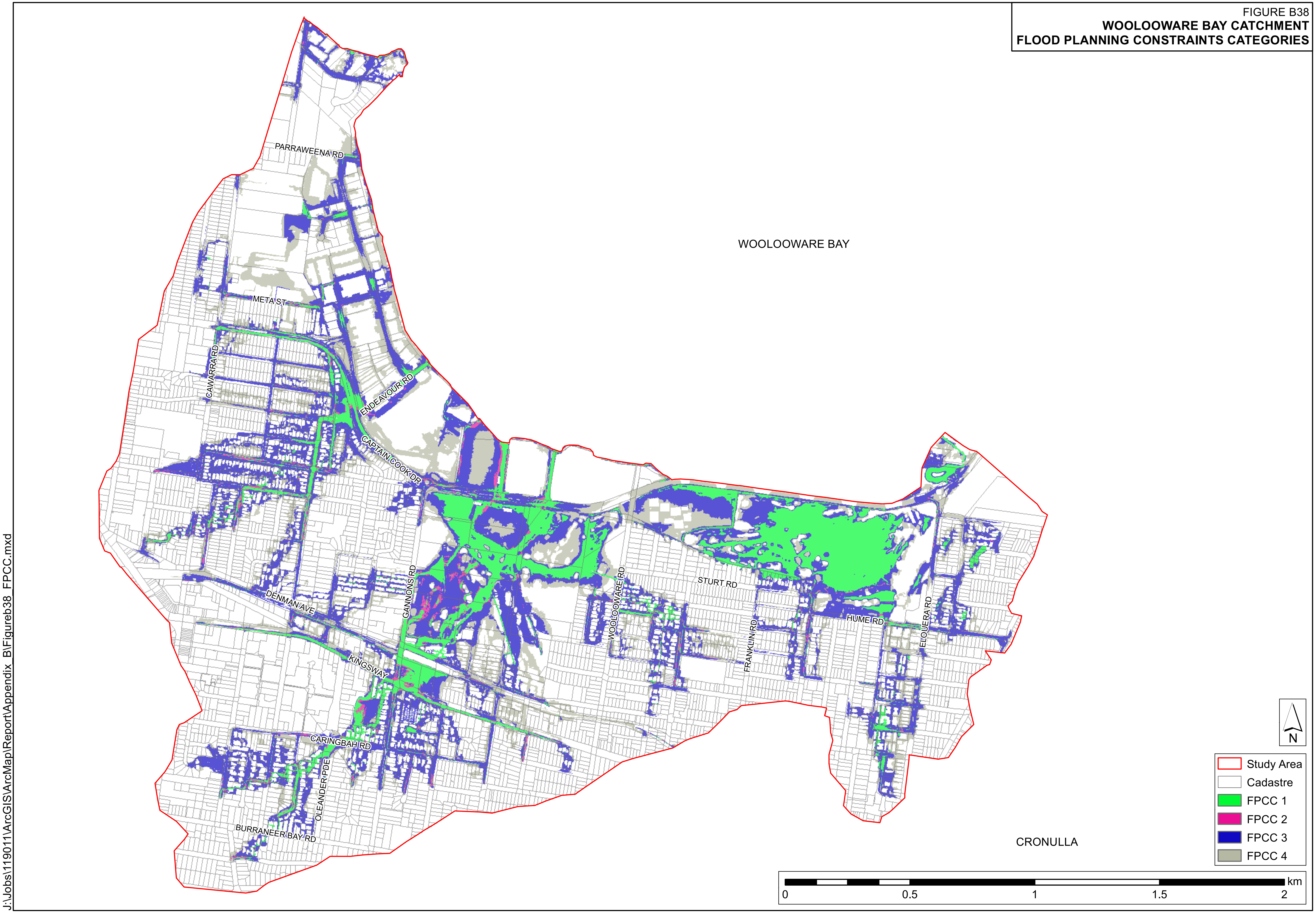

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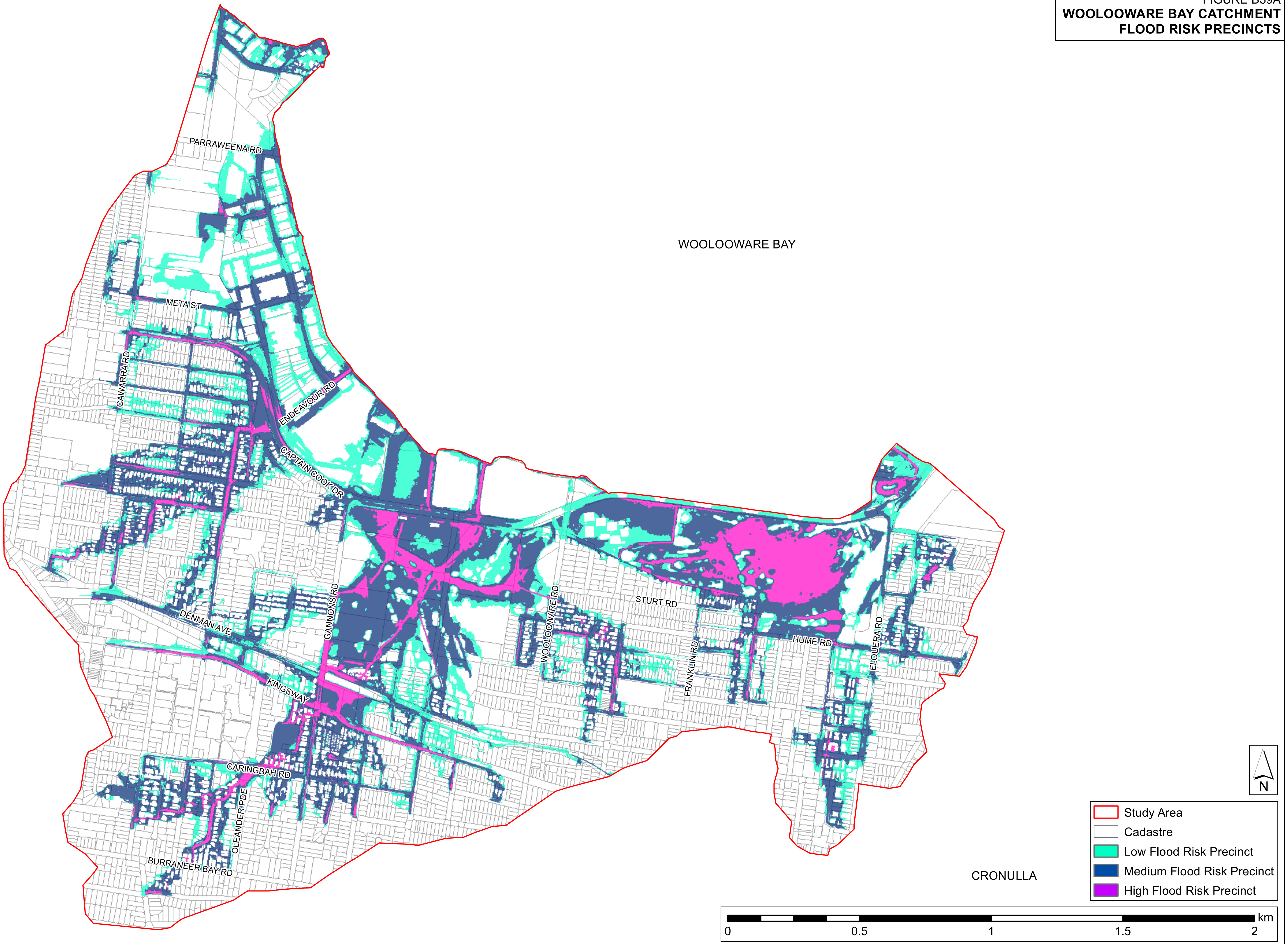
FIGURE B39A

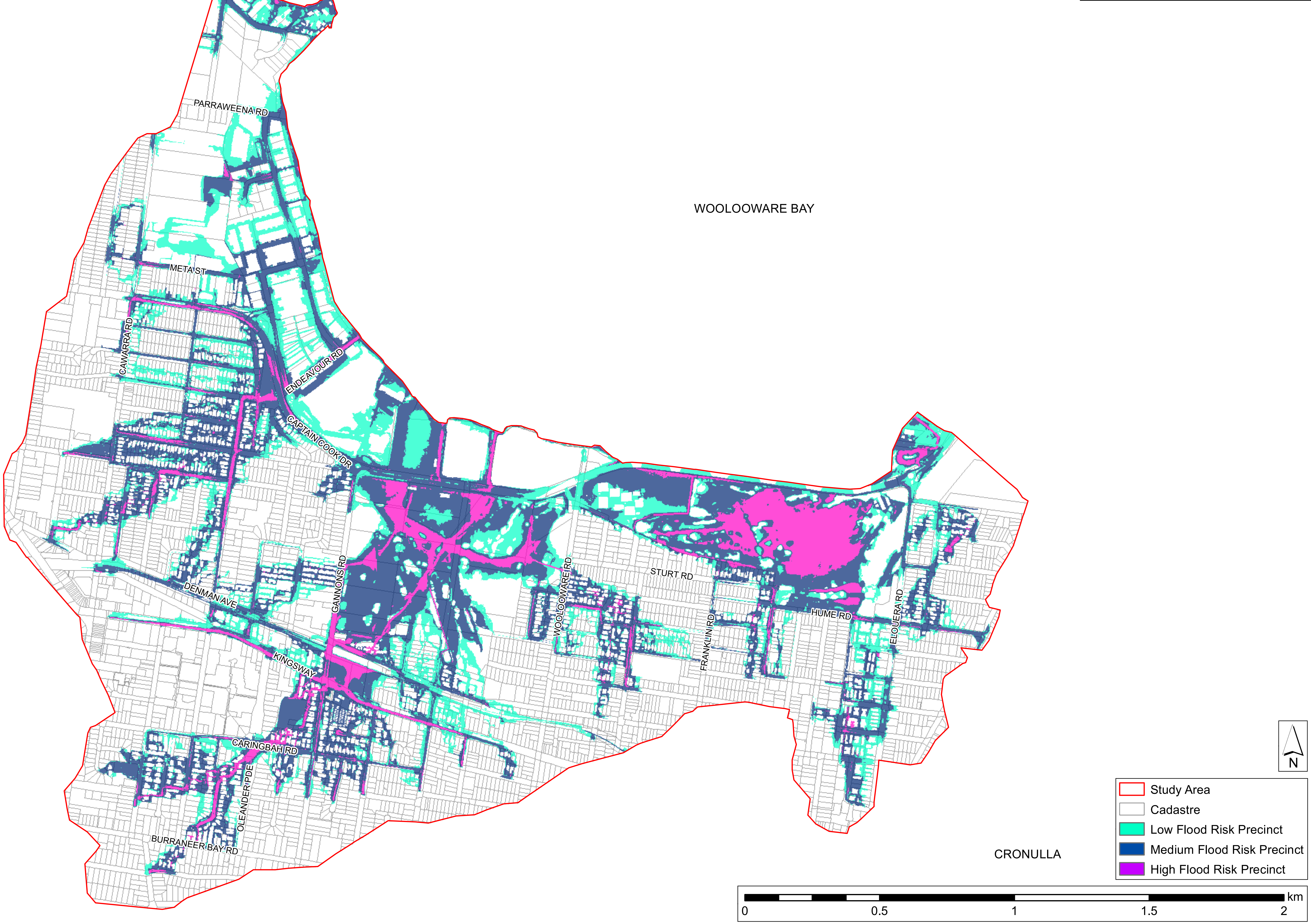
WOOLOOWARE BAY CATCHMENT FLOOD RISK PRECINCTS



J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix B\FigureB39A Flood Risk Precincts 2019AR&R trimmed.mxd

FIGURE B39

WOOLOOWARE BAY CATCHMENT
FLOOD RISK PRECINCTS



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Revision of 2014 Flood Study and ARR 2019 Sensitivity Analysis

Appendix C

APPENDIX C: REVISION OF 2014 FLOOD STUDY AND ARR 2019 SENSITIVITY ANALYSIS

C1: COMPARISON WITH RESULTS FROM 2014 FLOOD STUDY

As noted in Section 3.2, changes have been made to the TUFLOW model adopted in the 2014 Flood Study. The outcome of these changes is summarised below with a comparison of results provided in Appendix C figures. The comparison of results between the 2014 and the current study was undertaken for the 1% AEP event using ARR 1987 (as this version of ARR was adopted in the 2014 Flood Study).

This project was completed over a period of three years and during that time several large and small changes to the TUFLOW model have been undertaken. All mapping, modelling and result files in Appendix B and provided to Council have adopted the most up to date TUFLOW model. The early comparison results provided in Appendix C were undertaken using prior TUFLOW models and for various technical and other reasons these results could not be subsequently updated using the final TUFLOW model. Thus, these model runs cannot now be exactly replicated.

C1.1 Change in ALS

A comparison of the 2007 ALS adopted in the 2104 Flood Study and the 2013 ALS adopted in the present study is provided on Image C1. This figure indicates:

- There are four major changes to the topography: at the new commercial / light industrial subdivision off Cawarra Road, Caringbah; on approximately 3 fairways on Cronulla golf course; at Shearwater Estate north of Bate Bay Road and associated with the residential development near the football ground on the north side of Captain Cook Drive.
- There is a general reduction in ground level (blue tones) across the entire catchment. However, it is noted that on the two golf courses the change is only within the tree lined areas adjacent to the fairways. This suggests that this may be due to a different approach to obtaining ground levels through vegetation cover.

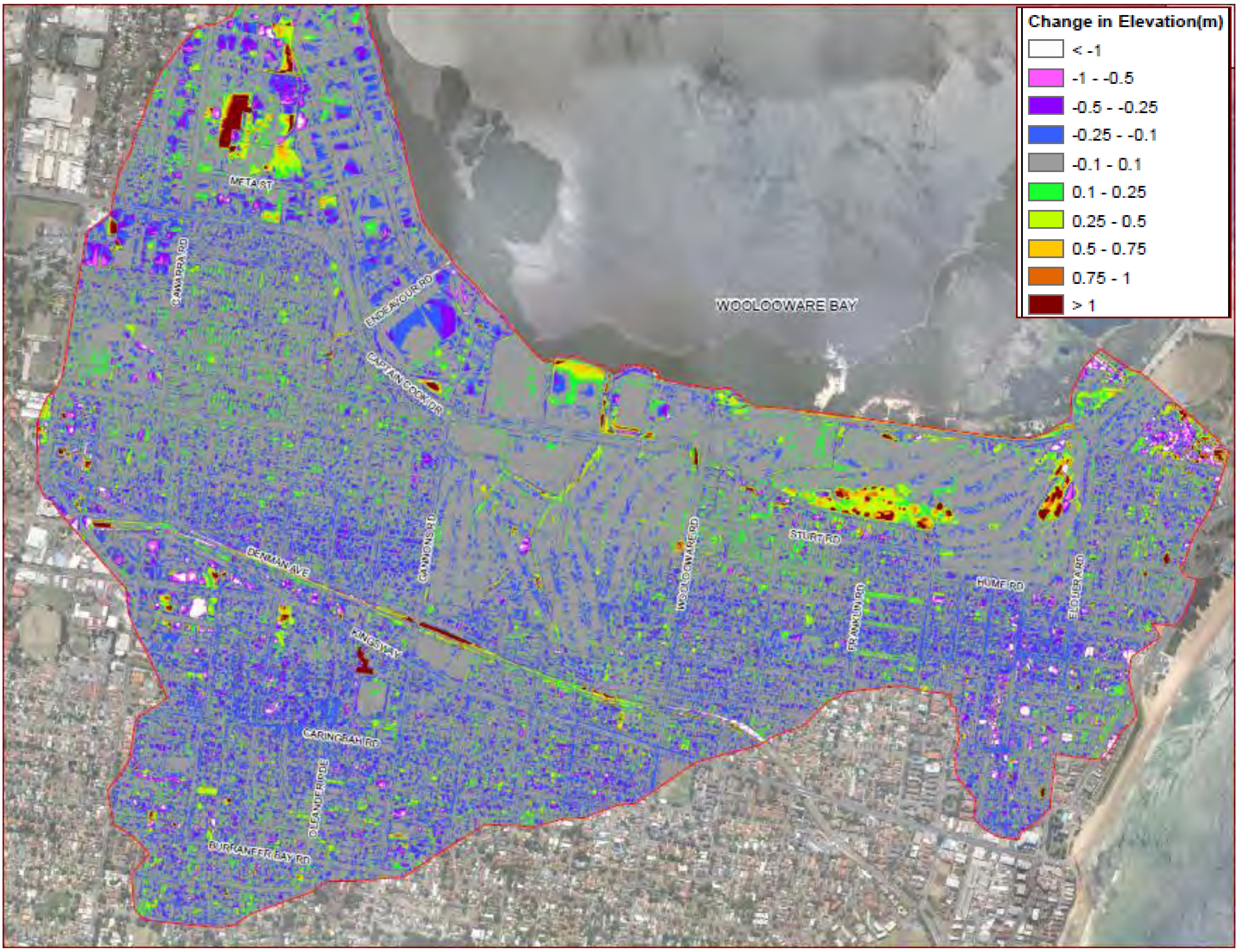

Image C1: Comparison of 2007 versus 2013 ALS

ALS forms the basis of the TUFLOW model as it describes the topography which in turn defines the flow paths, flood depths and flood levels that are adopted for development control purposes. The benefit of using ALS rather than traditional field survey to define the topography is that it would be cost prohibitive to obtain the point definition available from ALS (approximately every 1m spacing). The accuracy of ALS has improved significantly in the last 15 years as has the ability of the ALS to define the ground level beneath trees. This has been tested as part of the present study by comparing surveyed levels at kerb inlet pits with the ground level from ALS. Generally, this shows a very good match thus confirming the accuracy of the ALS but it should be noted that there are limitations with the use of ALS such as:

- ALS is limited in its ability to obtain ground levels beneath heavy vegetation cover. In places ground levels are provided but it is likely that the accuracy will be less than in clear areas. In densely vegetated area no ground levels are provided and interpolation from adjacent ground levels is undertaken. This can introduce anomalies.
- ALS cannot distinguish between a pergola / verandah / car port which has clear space beneath and a solid structure. This level of detail can only be picked up by field inspection and can easily be missed.

- Brick fences which act as impermeable barriers to flow are unlikely to be picked up and can only be picked up by field inspection and can easily be missed.
- ALS generally only provides ground levels every 1m spacing thus cannot generally be used to define kerb and guttering along a road. For this reason, kerb and guttering are manually imported into TUFLOW.

A comparison of 1% AEP peak levels using ARR 1987 for the 2007 and 2013 ALS is provided on Figure C1.

C1.2 Implementation of Revised Stormwater Database

A comparison between the pit and pipe network adopted in the 2014 TUFLOW model and the updated survey is provided in Image C2 where the 2014 v 2019 survey pit and pipe network is provided together. The blue lines show where new pipes have been found. The effect of inclusion of these pipes was minimal and only affected the localised area as shown on Figure C2. The changes shown in Image C2 in Woolooware and Cronulla golf courses have no bearing on the results as these are open channels.

Image C2: Comparison of 2014 v 2019 Survey of the Pit and Pipe Network

C1.3 Effect of New Development

As noted in Section 3.2 the following developments have occurred since publication of the 2014 Flood Study and the effect of these are provided on Figure C3:

- Upgrading of Captain Cook Drive adjacent to Cronulla golf course.
- The approved residential developments and road works adjacent to the football ground.
- Earthworks within Cronulla golf course.
- Earthworks on the Shearwater Estate.
- Construction of noise walls along Captain Cook Drive adjacent to the former Toyota site.
- Widening of the Gannons Road rail overbridge.
- Earthworks and construction of buildings on Wurrook Circuit off Cawarra Road.

C1.4 Effect of Changing from ARR 1987 to ARR 2019

Details of the ARR 2019 approach are provided in Appendix F and the comparison of results are provided on Figure C4.

C1.5 Effect of Changing from 2011 Version of TUFLOW (adopted in 2014 Flood Study) to Current Version

Details of the TUFLOW version are provided in Section 3.2 and a comparison of results is provided on Figure C5.

C1.6 Change in Grid Cell Size

The TUFLOW model in the 2014 Flood Study adopted a 3m grid size due to the long model run times using TUFLOW Classic. Greater grid cell size definition enables more precise modelling of the flow paths in and around buildings (generally less than 2m wide separates the buildings on each side). Using the HPC version of TUFLOW (Section 3.2) enables much shorter run times and thus a smaller grid can be adopted. The effect of changing the grid size from 3m to 1m was investigated and the resulting impact on peak flood levels is provided in Figure C6. The results indicate minimal change in flood level except in areas where the flow paths were narrow and thus could not be accurately defined with a 3m grid.

C1.7 Combined Effect of New Stormwater Database and ARR 2019

The results of the combined effect of the new stormwater database and ARR 2019 are provided on Figure C7.

C1.8 Effect of Revised Building Extents

As part of the current study some building extents were revised based on the inclusion of additional survey data. A comparison of results is provided on Figure C8.

C1.9 Change in 1% AEP Peak Levels (ARR 2019) using Updated Model v 2014 Flood Study Model

Seven changes have been made to the 2014 Flood Study model, namely:

- Updated ALS.

- Updated stormwater database.
- Inclusion of recent developments (e.g., Captain Cook Drive upgrade).
- Adoption of ARR 2019.
- Use of HPC TUFLOW rather than TUFLOW Classic.
- 1m grid rather than 3m grid.
- Revised building envelopes.

The TUFLOW model adopted in the 2014 Flood Study was updated to include the above changes and a comparison of results is provided on Figure 4 and Figure C9 (same figure). The results indicate:

- In the lower part of the catchment and on the two golf courses there is little change in peak levels.
- There are some significant areas with reduction in peak levels near Kirkwood Road and Berry Street, Cronulla; in the small open channel between Elouera Road and Wyanbah Road, Cronulla and west of the new commercial / light industrial subdivision off Cawarra Road, Caringbah.
- There are also many areas of isolated reduction in flood levels or now no longer flooded. This is largely due to the reduced rainfall intensities using ARR 2019.
- There are a few areas which are now flooded but were not previously (i.e., the extent of the 1% AEP floodplain has generally not increased to any significant extent).

C1.10 Comparison of 1% AEP Peak Levels (ARR 1987) using Rainfall on the Grid Modelling

The TUFLOW model adopted in the 2014 Flood Study used DRIANS as the hydrologic model. An alternative hydrologic approach is to use rainfall on the grid and a comparison of results between the 2014 Flood Study 1% AEP peak levels (ARR 1987) and the same event using rainfall on the grid is provided on Image C3 (blue tones indicate lower levels with the current data). This figure indicates:

- In the lower western part of the catchment there are reduction in peak levels of up to -250mm.
- There are many areas shown as newly flooded. This is to be expected as many of these areas would be upstream of the DRAINS model inflow point.
- The additional storage volume within the "red" areas would attenuate the peak flow and thus contribute to the reduction in peak levels downstream.

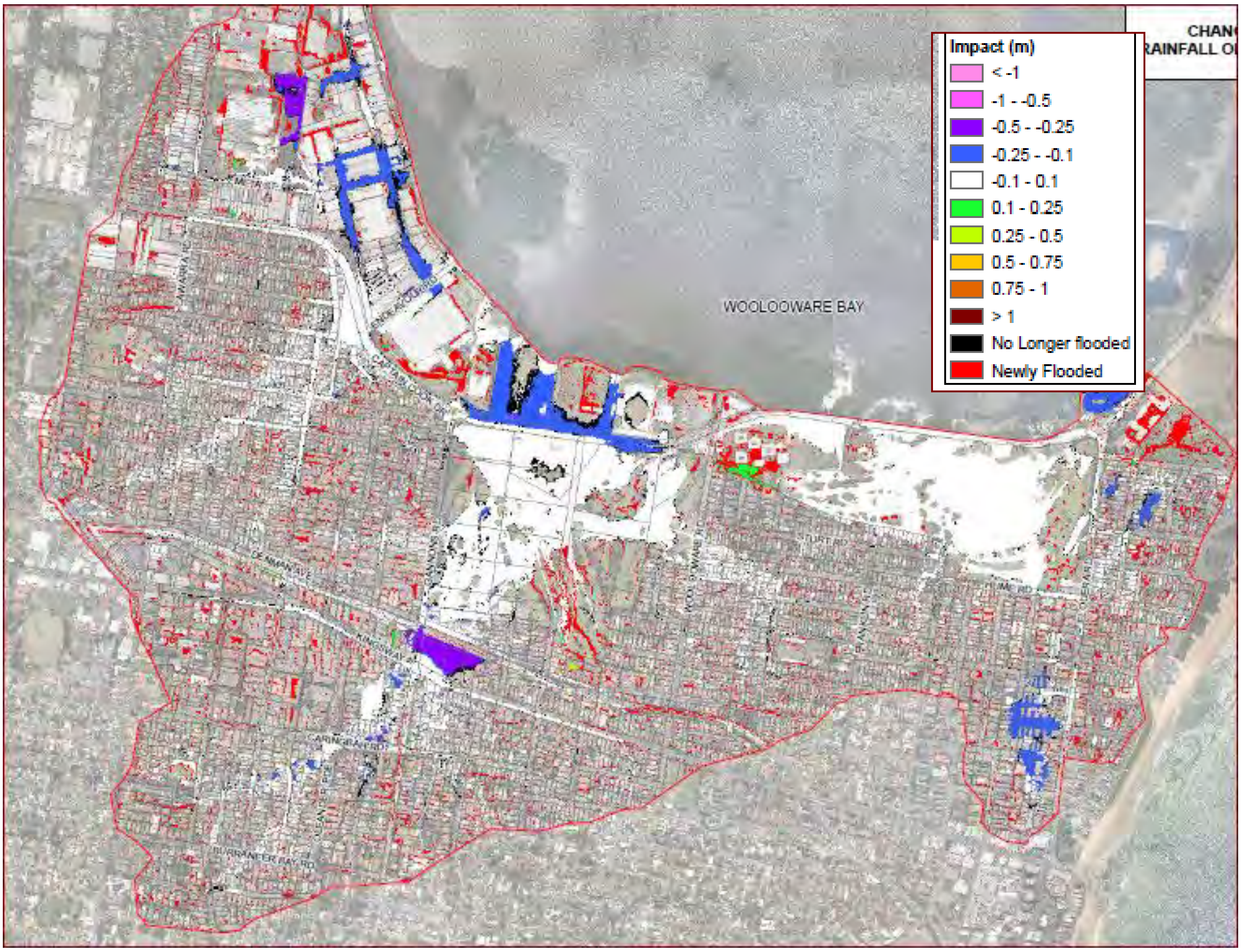

Image C3: Comparison of 2014 v Rainfall on the Grid TUFLOW model 1% AEP

C2: Sensitivity Analysis: Updated Model

As part of any Flood Study sensitivity analysis is undertaken to assess the effects of varying modelling parameters. The results for the 5% and 1% AEP events are provided on Figure C10 to Figure C31 for:

- 50% change in rainfall loss (Figure C10 to Figure C13).
- 50% change in hydrologic lag (Figure C14 to Figure C17).
- 25% change in hydraulic roughness (Figure C18 to Figure C21).
- varying effect of blockage (Figure C22 to Figure C27).
- varying effect of tailwater level (Figure C28 to Figure C31).

FIGURE C1
WOOLOOWARE BAY CATCHMENT CHANGE IN PEAK FLOOD LEVEL 2013 LIDAR V 2007 LIDAR 1% AEP EVENT, AR&R 1987

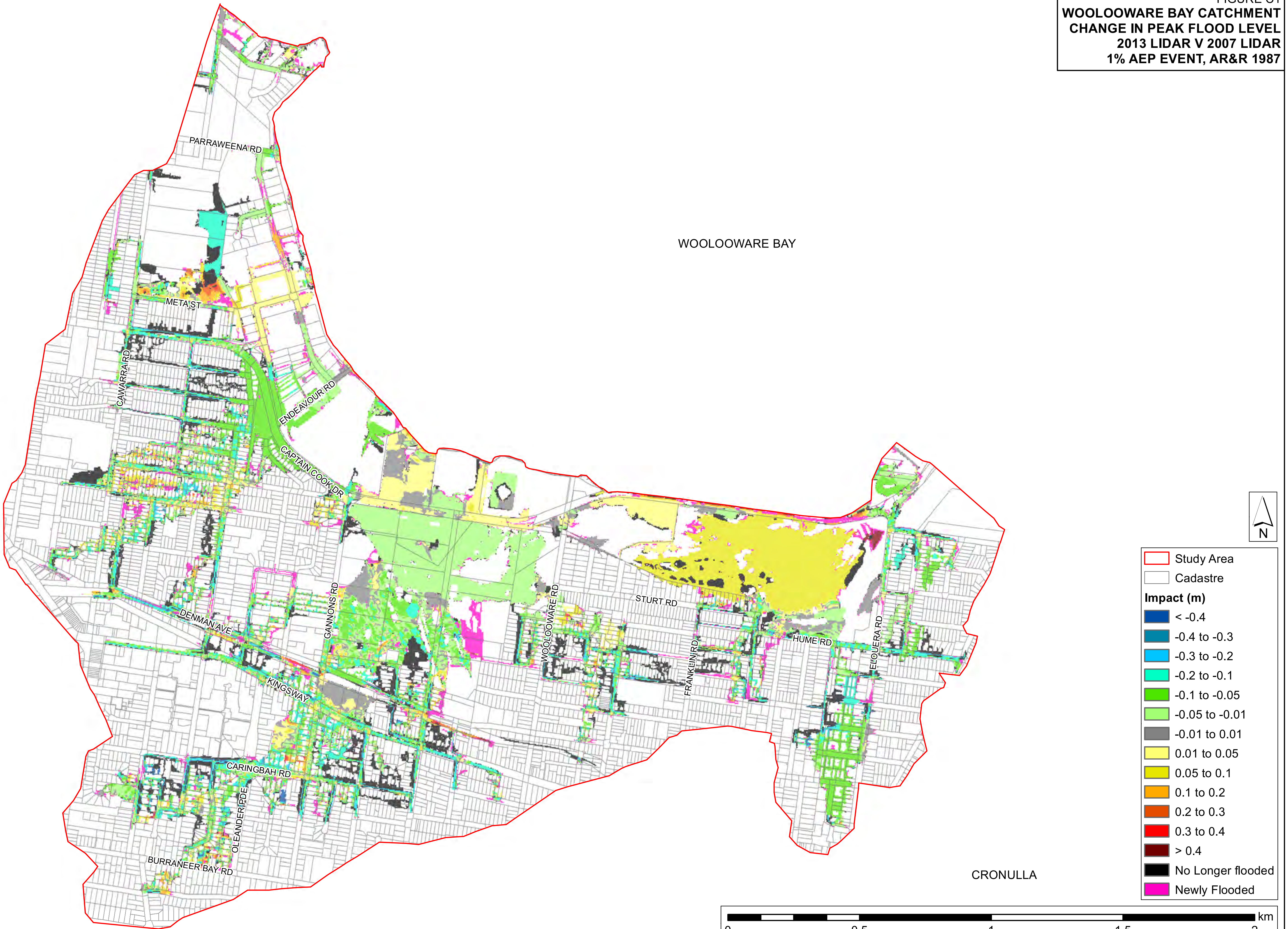

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FIGURE C2
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
IMPLEMENTATION OF REVISED STORMWATER DATABASE
1% AEP EVENT, AR&R 1987

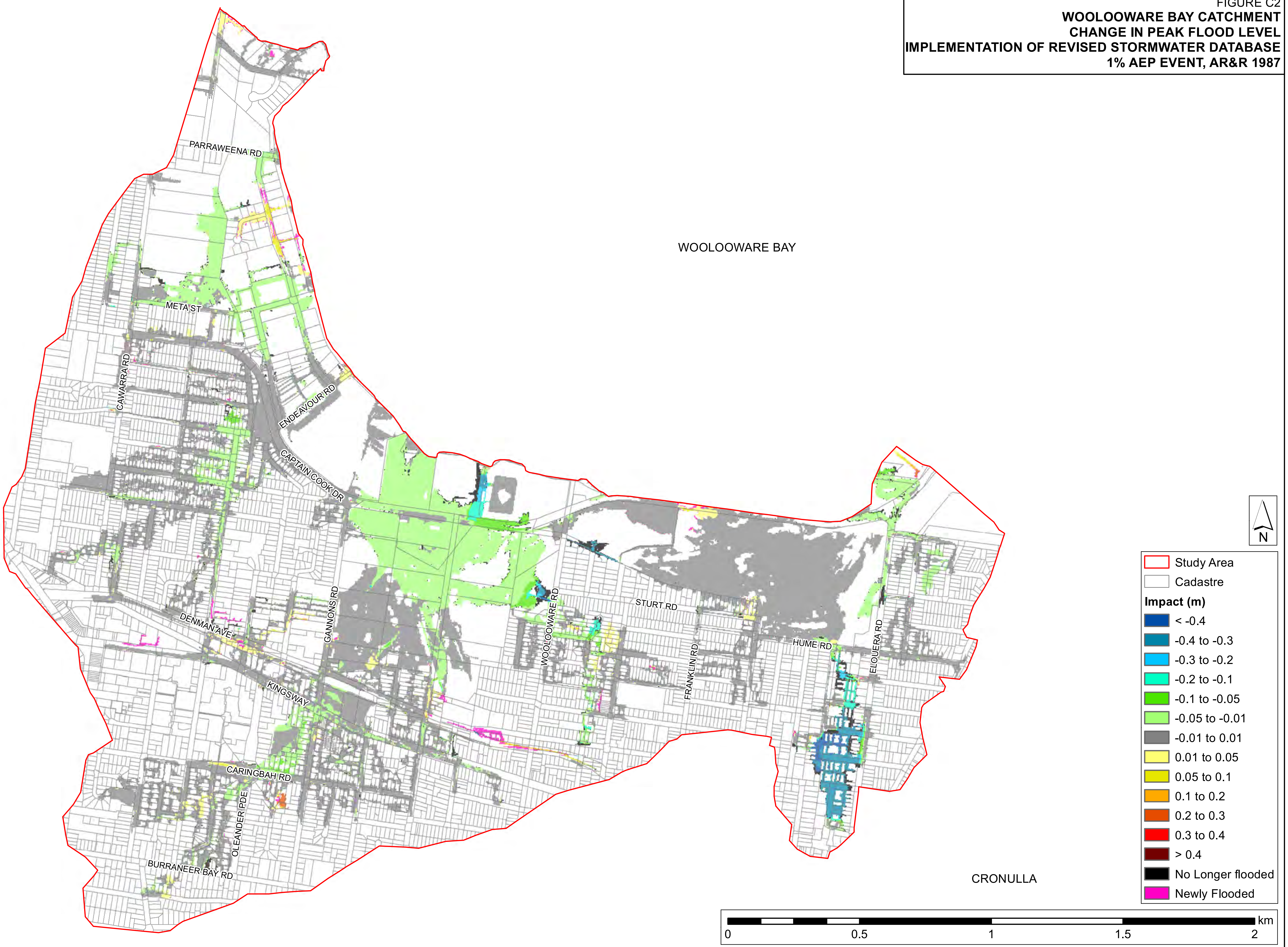

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FIGURE C3
WOOLOOWARE BAY CATCHMENT CHANGE IN PEAK FLOOD LEVEL NEW DEVELLOPMENT 1% AEP EVENT, AR&R 1987

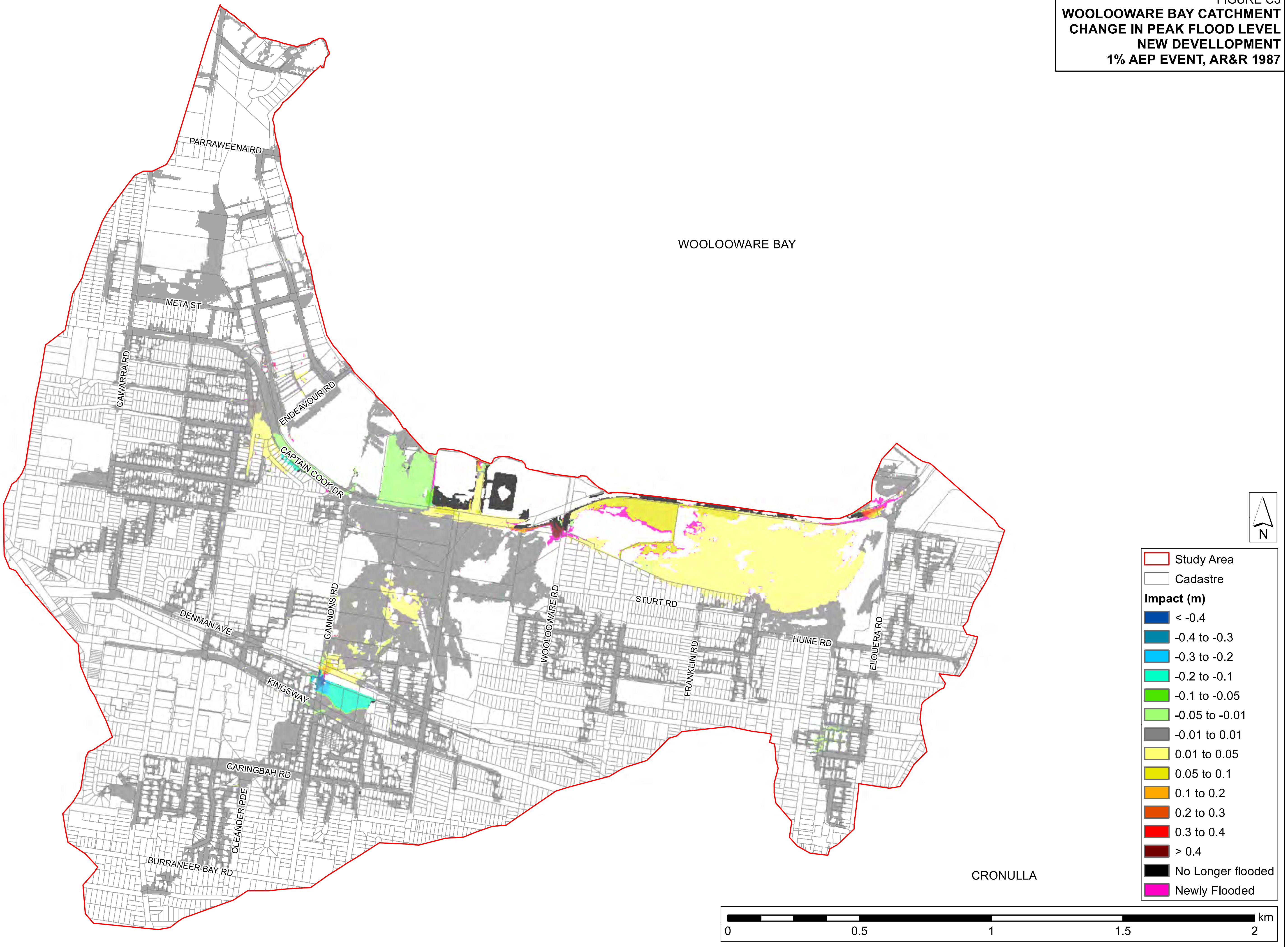

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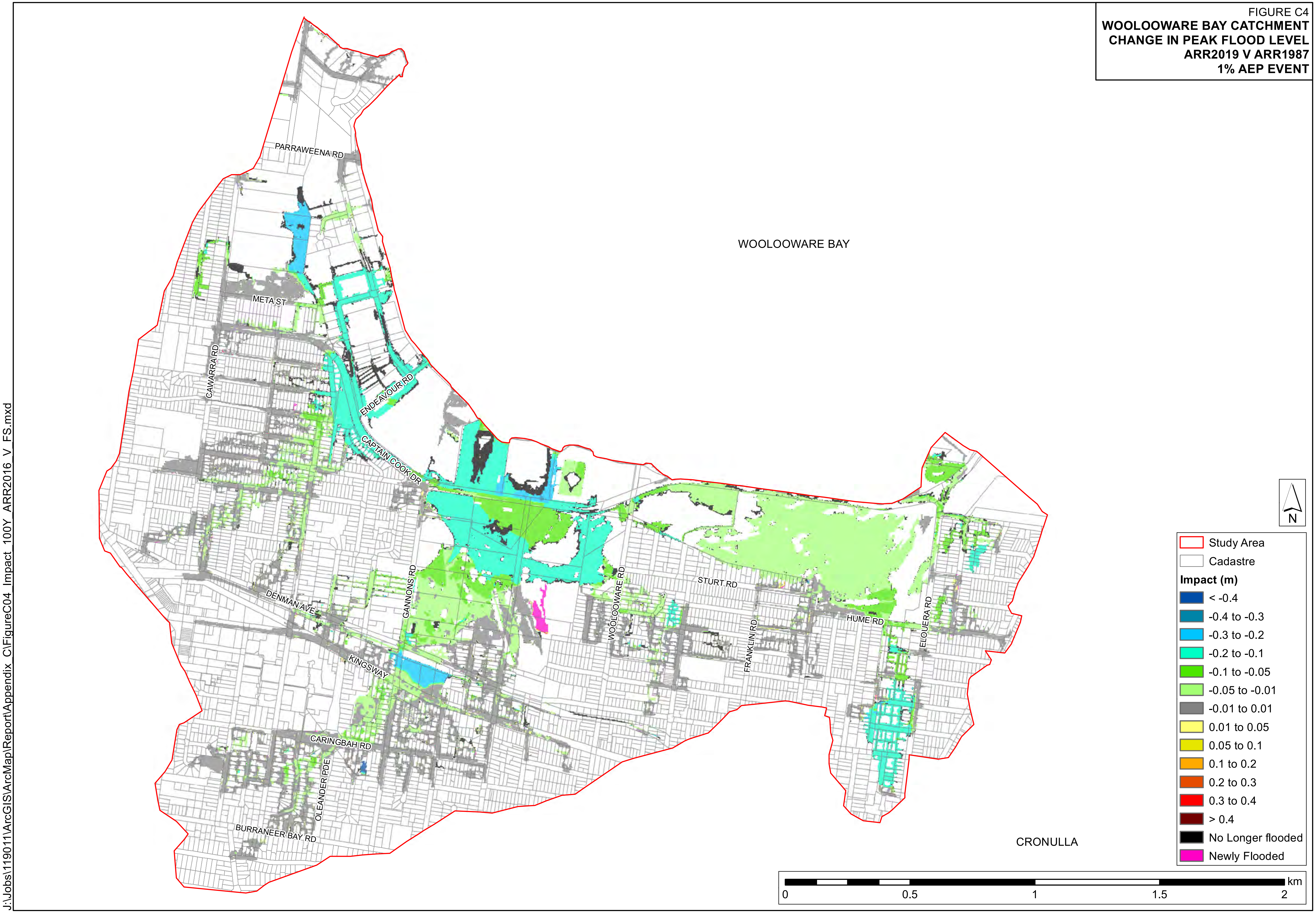
FIGURE C4
WOOLOOWARE BAY CATCHMENT CHANGE IN PEAK FLOOD LEVEL ARR2019 V ARR1987 1% AEP EVENT



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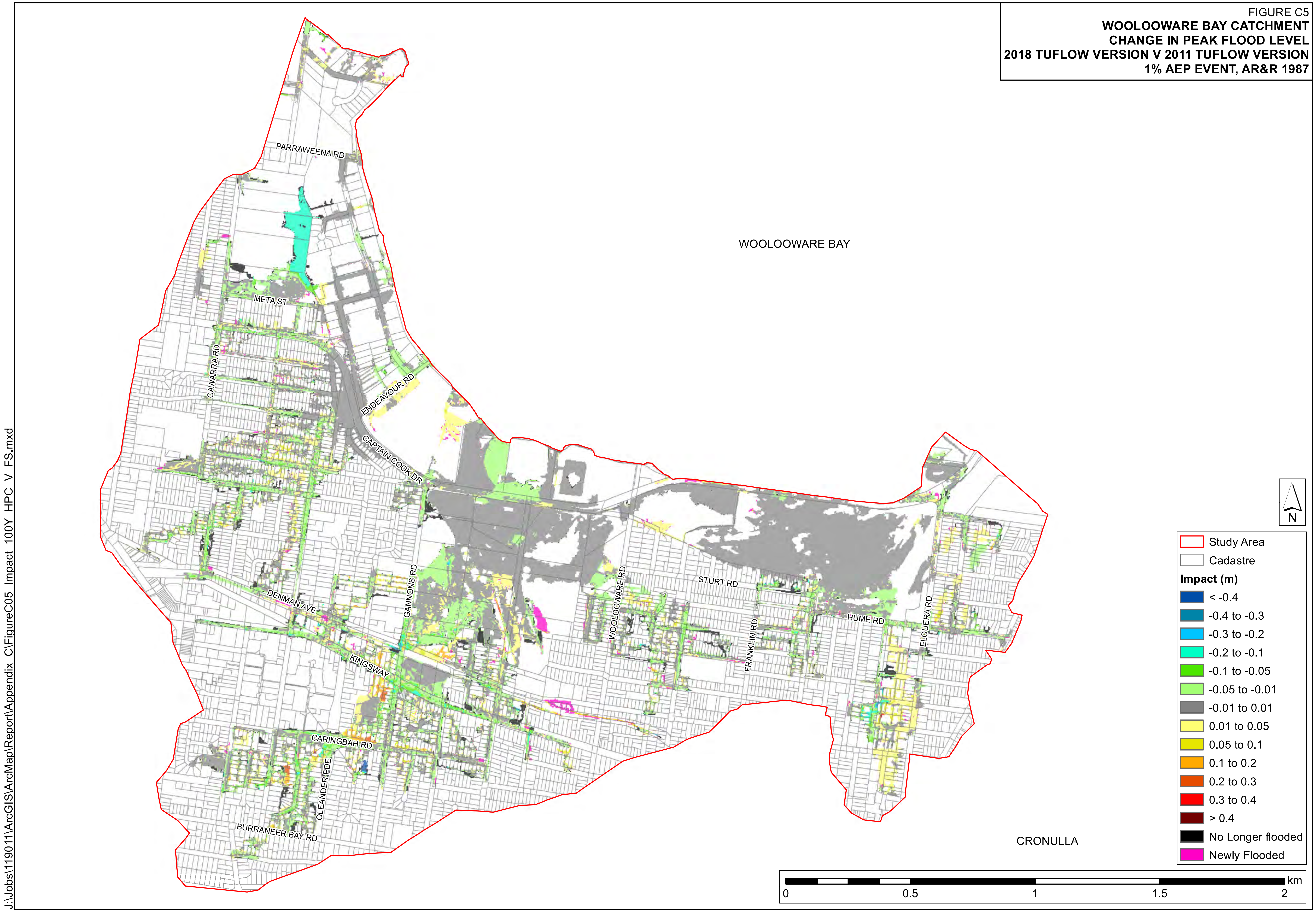
FIGURE C5
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
2018 TUFLOW VERSION V 2011 TUFLOW VERSION
1% AEP EVENT, AR&R 1987
WOOLOOWARE BAY
CRONULLA
PARRAWEENA RD
META ST
CAWARRA RD
ENDEAVOUR RD
CAPTAIN COOK DR
DENMAN AVE
KINGSWAY
GANNONS RD
CARINGBAH RD
OLEANDER PDE
BURRANEER BAY RD
WOOLOOWARE RD
STURT RD
FRANKLIN RD
HUME RD
ELOUERA RD
N
Study Area
Cadastre
Impact (m)
< -0.4
-0.4 to -0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
0.3 to 0.4
> 0.4
No Longer flooded
Newly Flooded
0
0.5
1
1.5
2
km
J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix C\FigureC05 Impact 100Y HPC V FS.mxd

FIGURE C6
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
1 METER CELLSIZE V 3 METER CELLSIZE
1% AEP EVENT, AR&R 1987

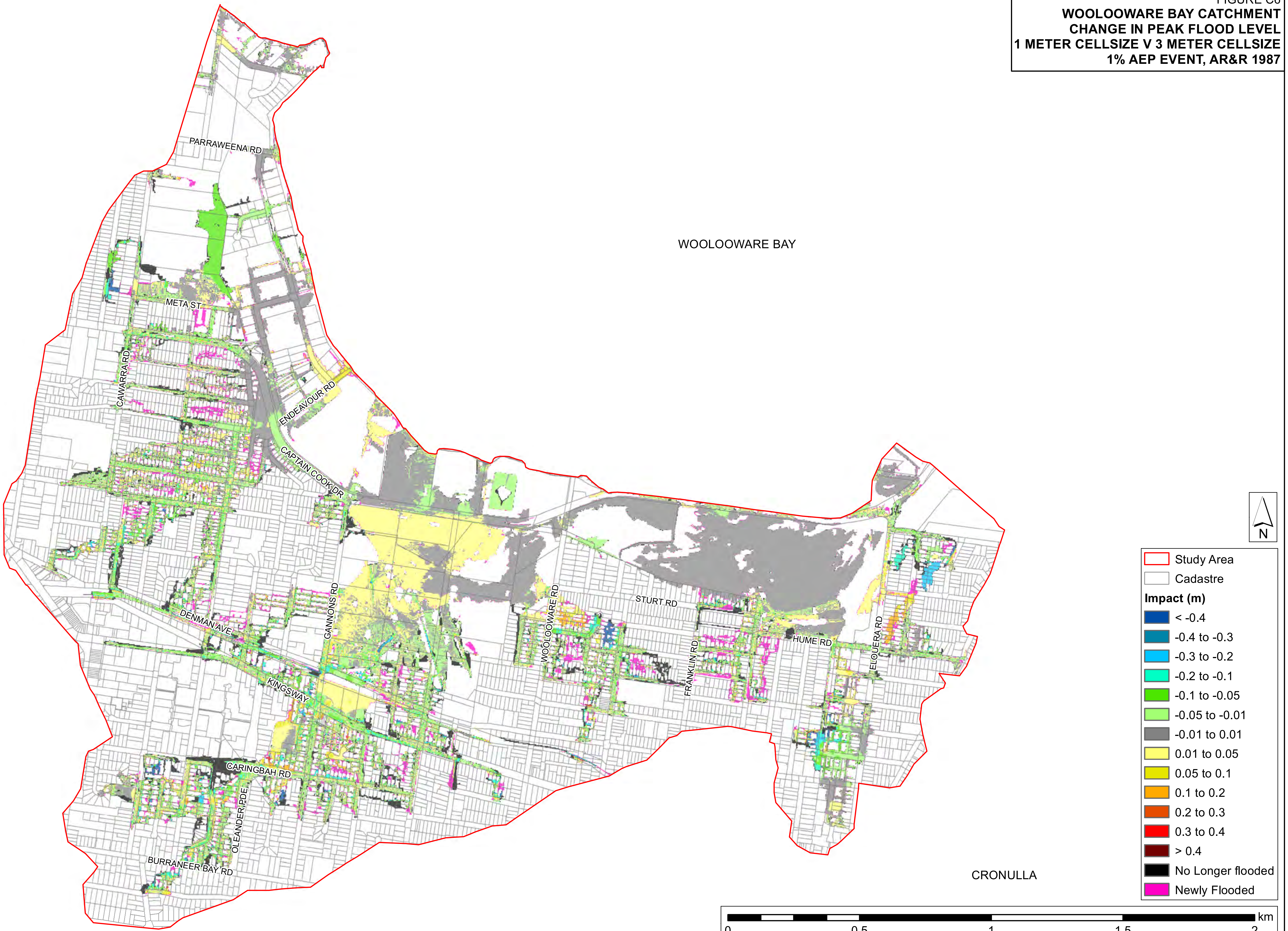

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FIGURE C7
WOOLOOWARE BAY CATCHMENT CHANGE IN PEAK FLOOD LEVEL NEW STORMWATER DATABASE AND ARR2019 1% AEP EVENT

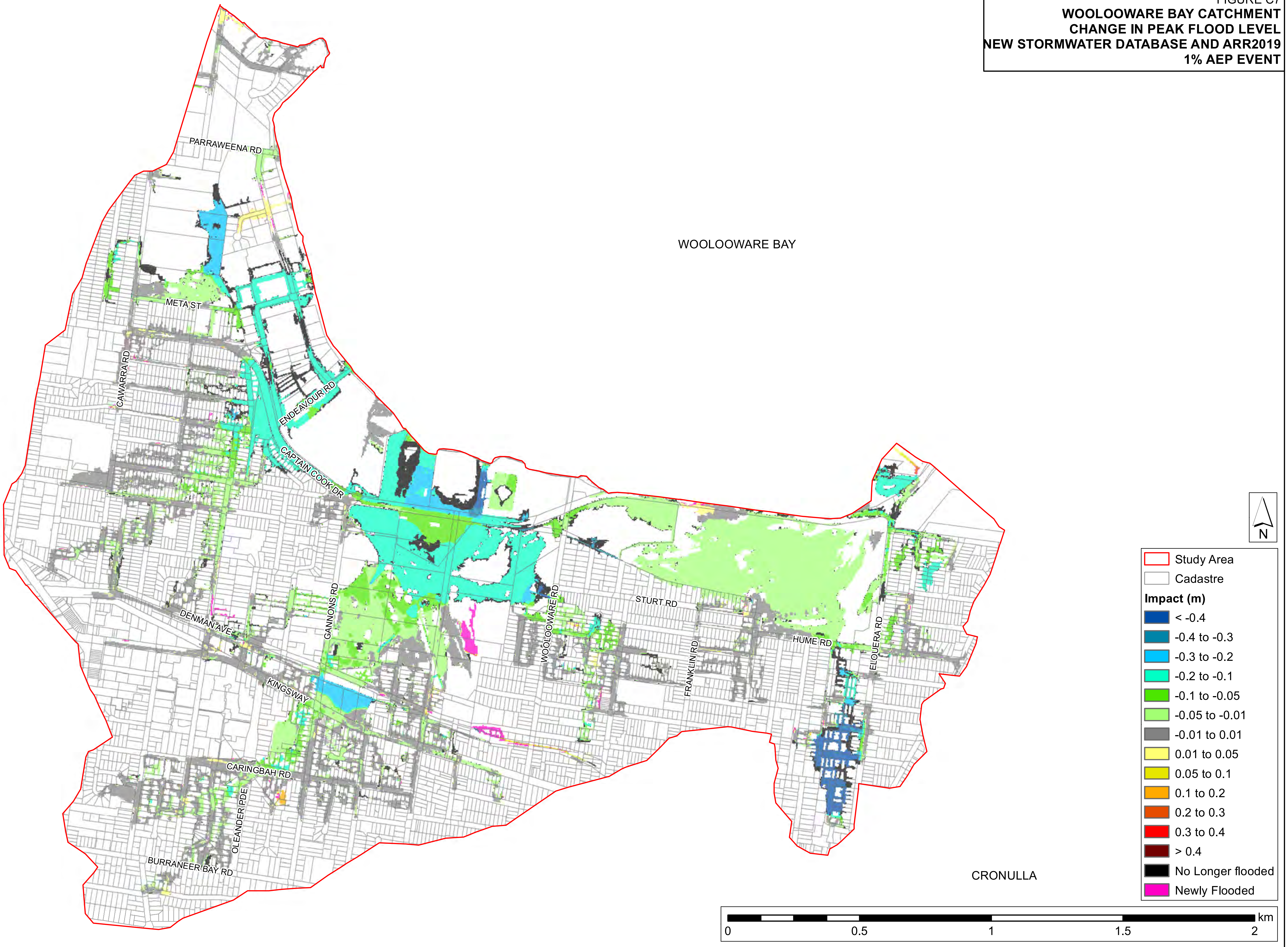

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FIGURE C8
WOOLOOWARE BAY CATCHMENT CHANGE IN PEAK FLOOD LEVEL REVISED BUILDING EXTENT 1% AEP EVENT, AR&R 1987

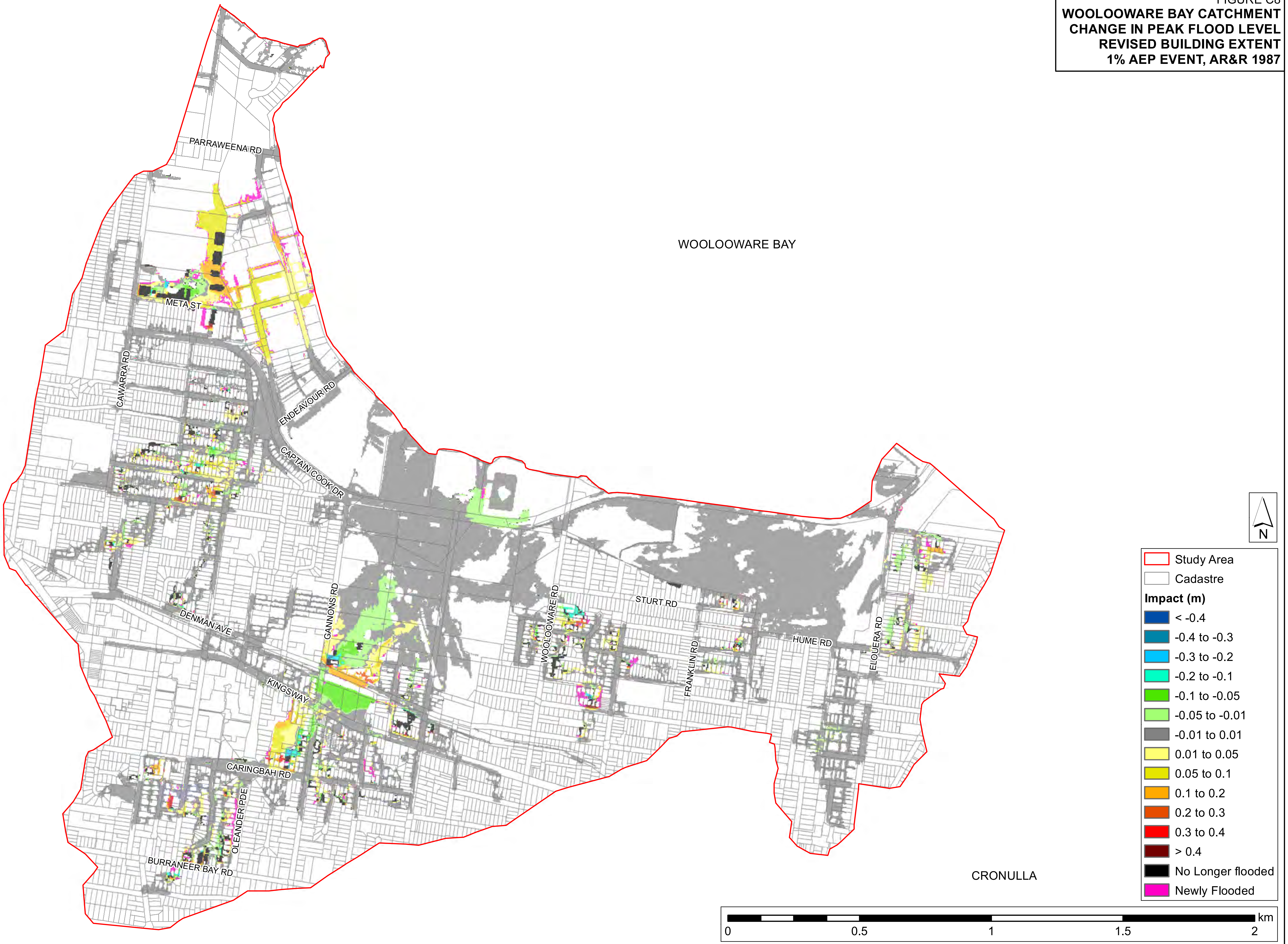

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FIGURE C9
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
REVISED MODEL ARR2019 V 2014 FLOOD STUDY ARR1987
1% AEP EVENT

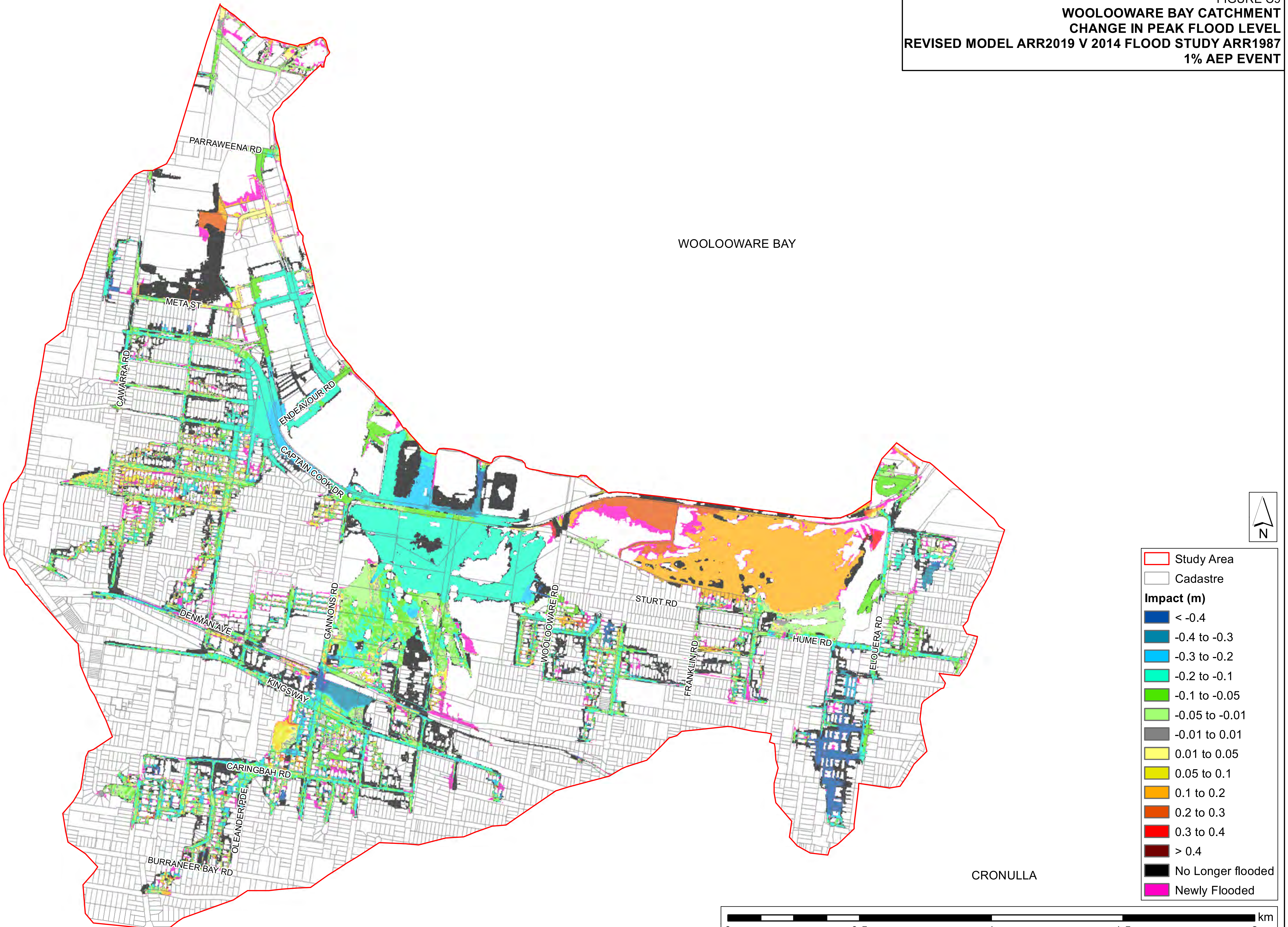

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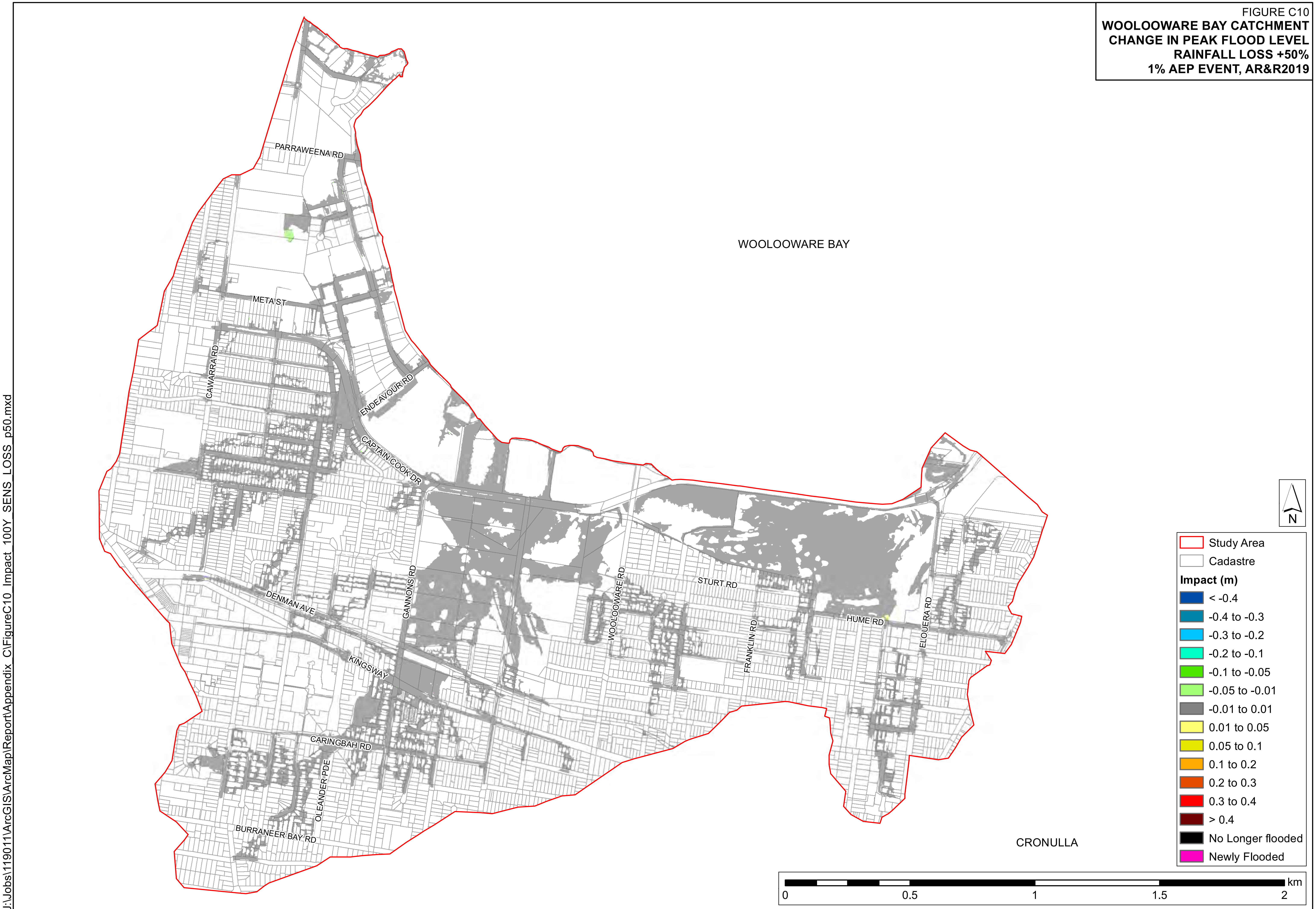
FIGURE C10
WOOLOOWARE BAY CATCHMENT CHANGE IN PEAK FLOOD LEVEL RAINFALL LOSS +50% 1% AEP EVENT, AR&R2019



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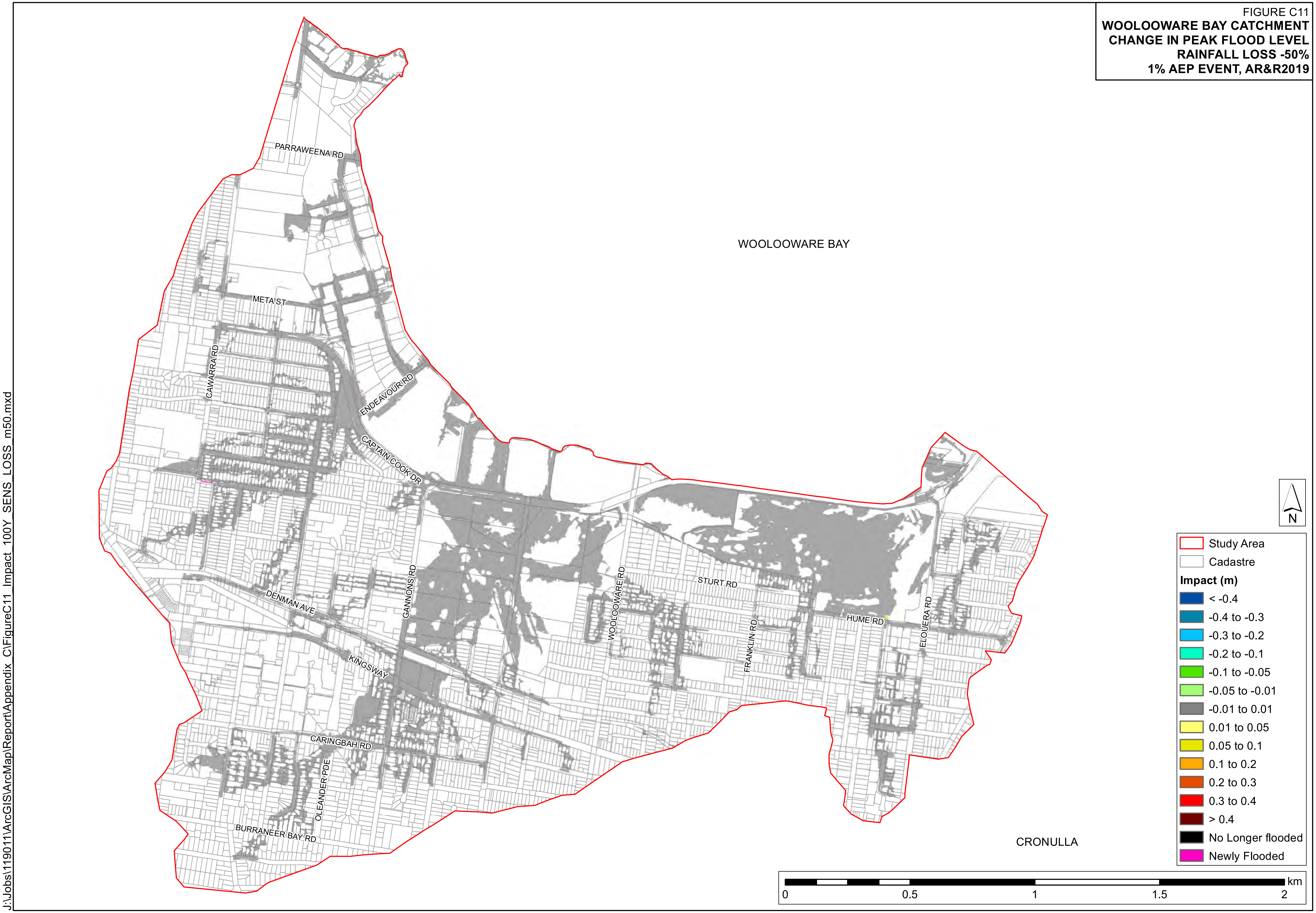
FIGURE C11
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
RAINFALL LOSS -50%
1% AEP EVENT, AR&R2019
WOOLOOWARE BAY
PARRAWEENA RD
META ST
CAWARRA RD
ENDEAVOUR RD
CAPTAIN COOK DR
GANNONS RD
DENMAN AVE
KINGSWAY
CARINGBAH RD
OLEANDER PDE
BURRANEER BAY RD
WOOLOOWARE RD
STURT RD
FRANKLIN RD
HUME RD
ELOUERA RD
CRONULLA
N
Study Area
Cadastre
Impact (m)
< -0.4
-0.4 to -0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
0.3 to 0.4
> 0.4
No Longer flooded
Newly Flooded
0
0.5
1
1.5
2
km
J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix C\FigureC11_Impact_100Y_SENS_LOSS_m50.mxd

FIGURE C12
**WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
RAINFALL LOSS +50%
5% AEP EVENT, AR&R2019**

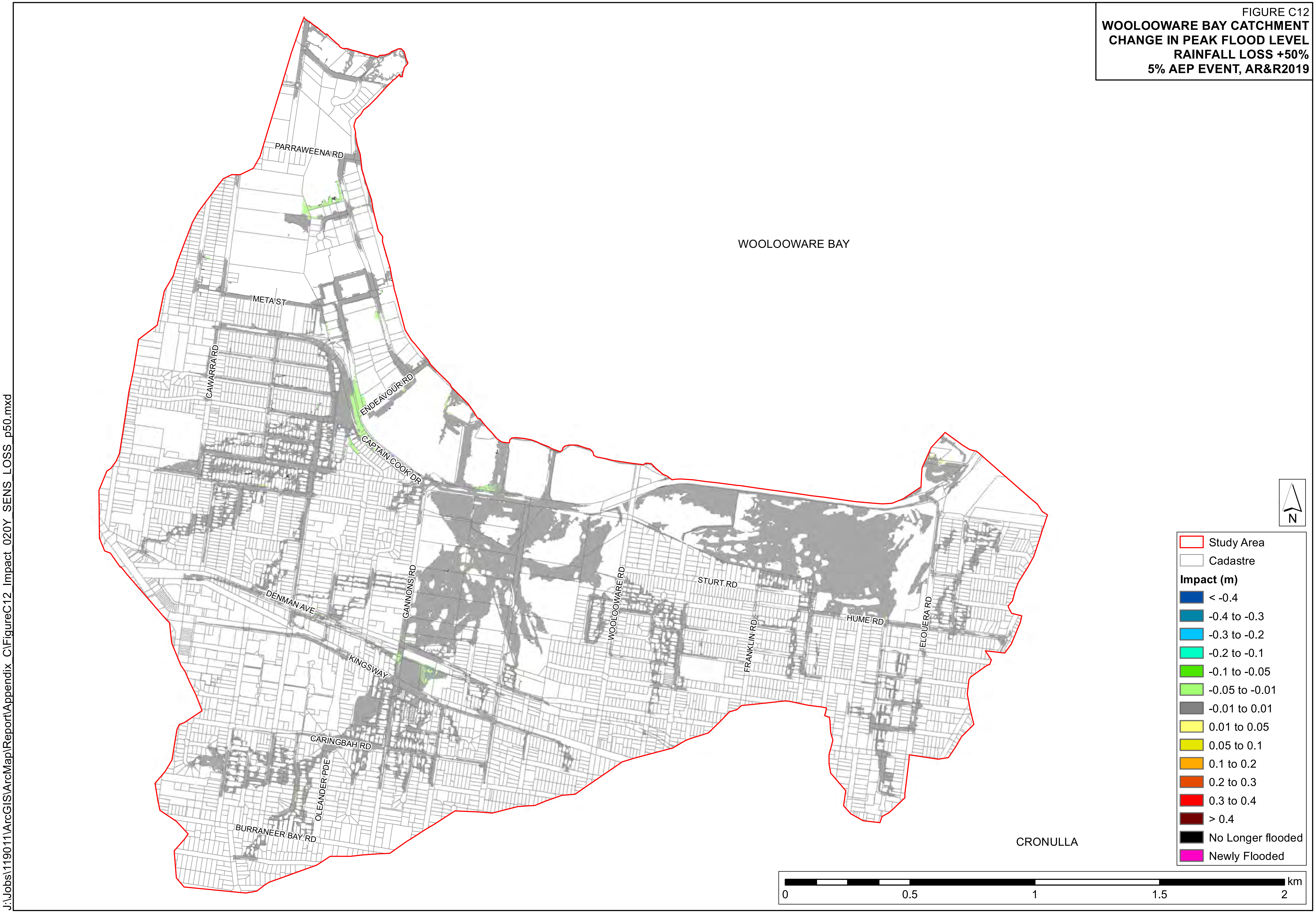

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FIGURE C13
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
RAINFALL LOSS -50%
5% AEP EVENT, AR&R2019

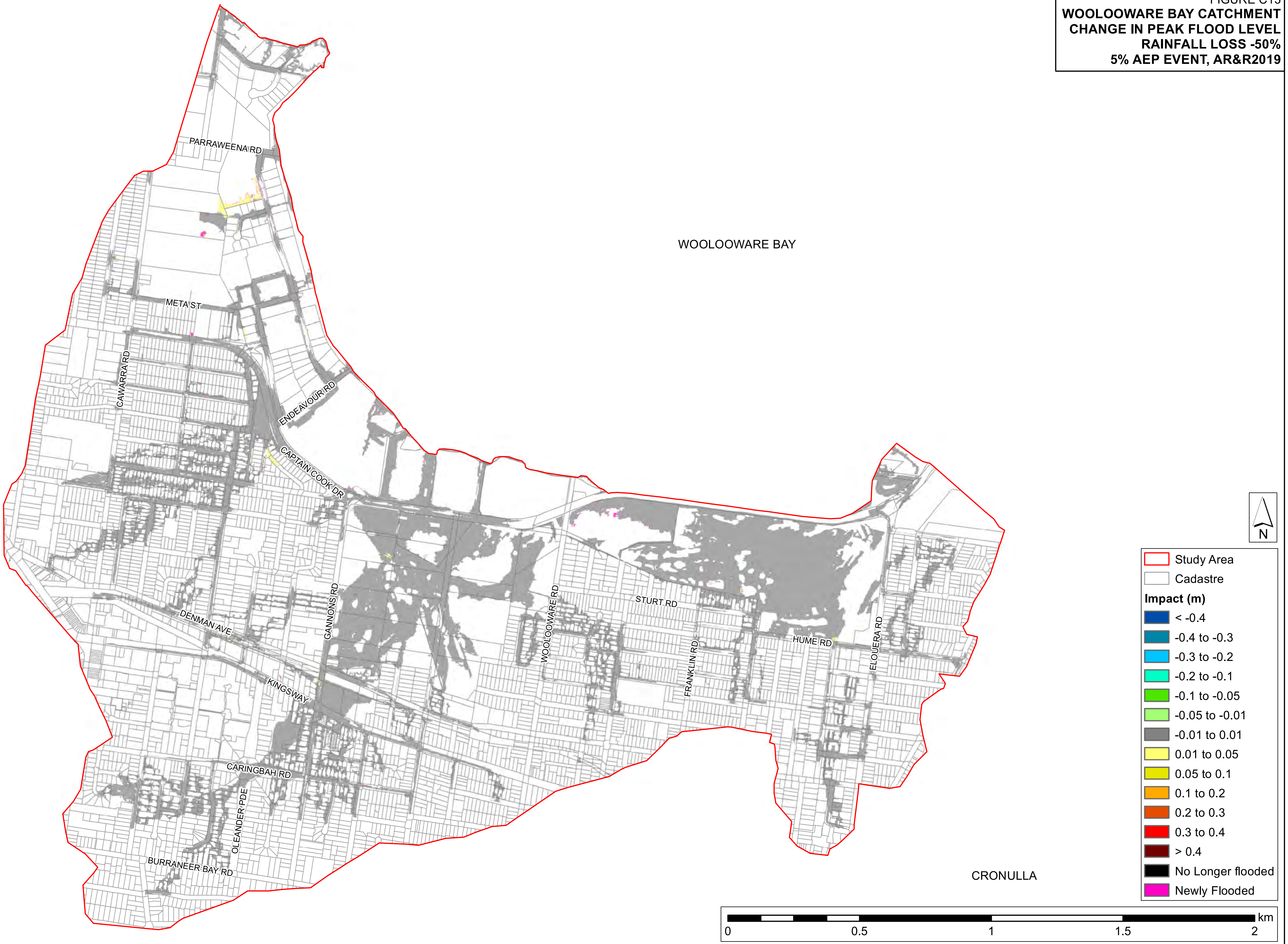

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FIGURE C14
WOOLOOWARE BAY CATCHMENT CHANGE IN PEAK FLOOD LEVEL HYDROLOGIC LAG +50% 1% AEP EVENT, AR&R2019

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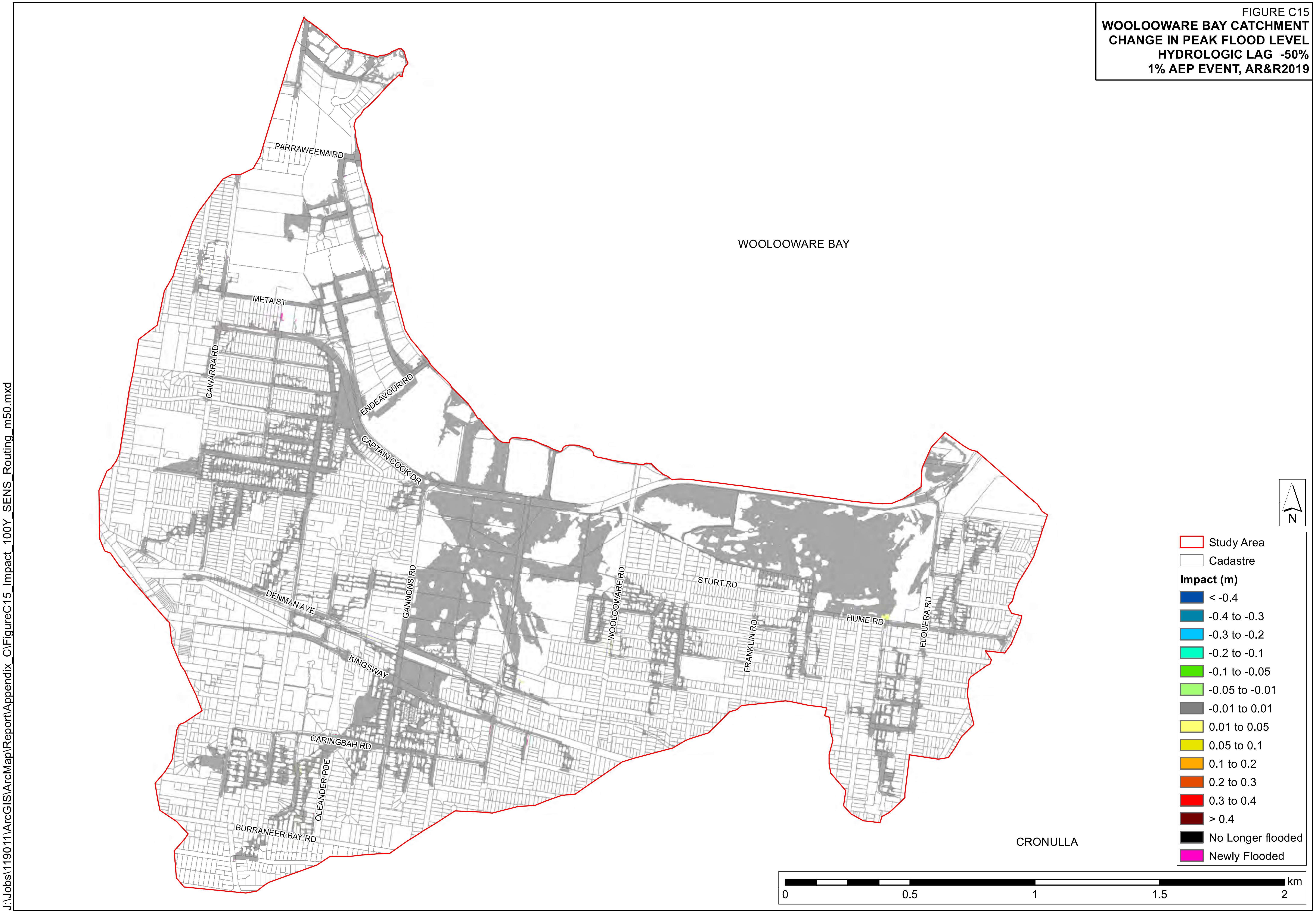
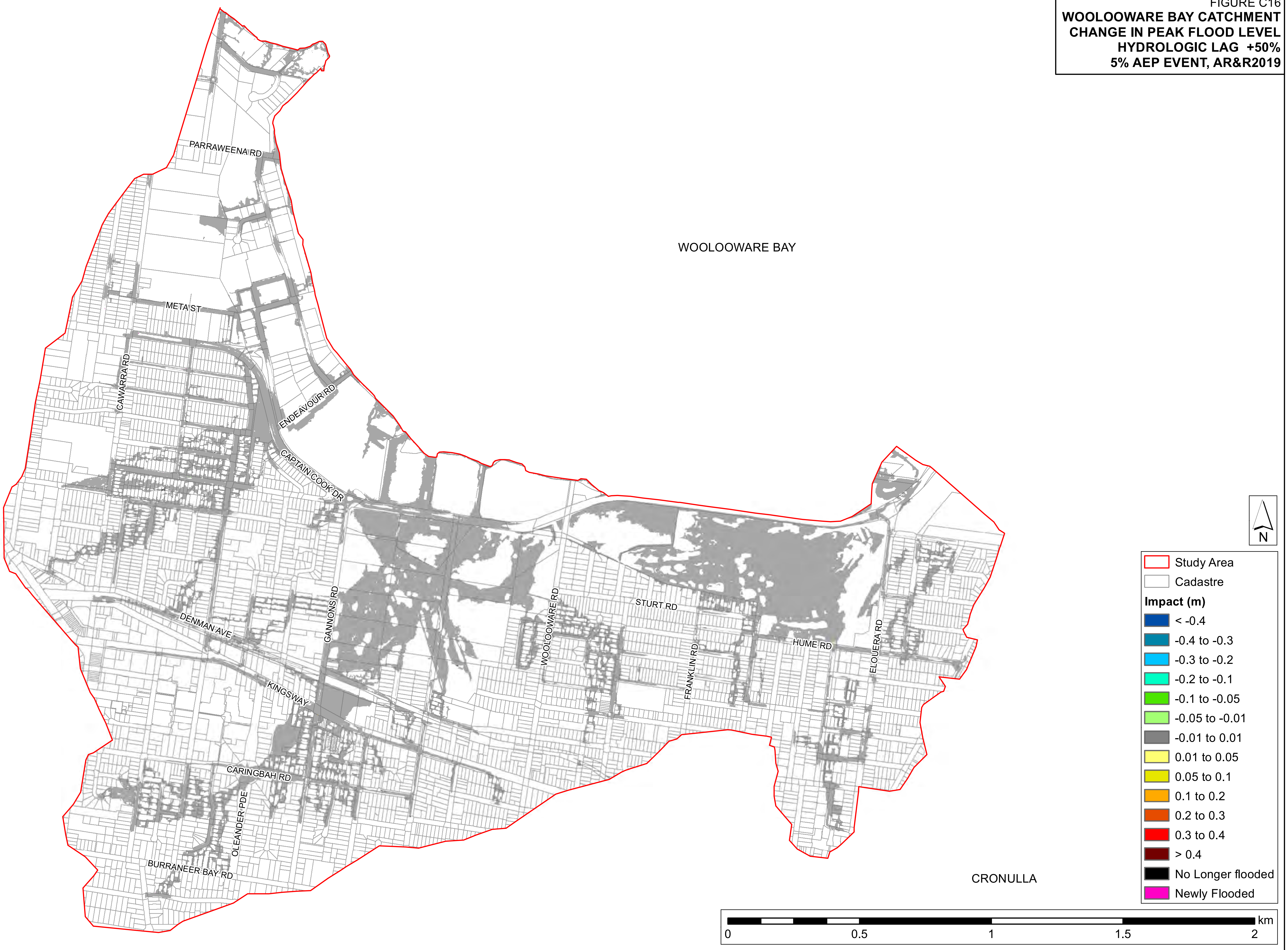
FIGURE C15
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
HYDROLOGIC LAG -50%
1% AEP EVENT, AR&R2019



J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix C\FigureC15_Impact_100Y_SENS_Routing_m50.mxd

FIGURE C16
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
HYDROLOGIC LAG +50%
5% AEP EVENT, AR&R2019



J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix C\FigureC16_Impact_020Y_SENS_Routing_p50.mxd

FIGURE C17
WOOLOOWARE BAY CATCHMENT CHANGE IN PEAK FLOOD LEVEL HYDROLOGIC LAG -50% 5% AEP EVENT, AR&R2019

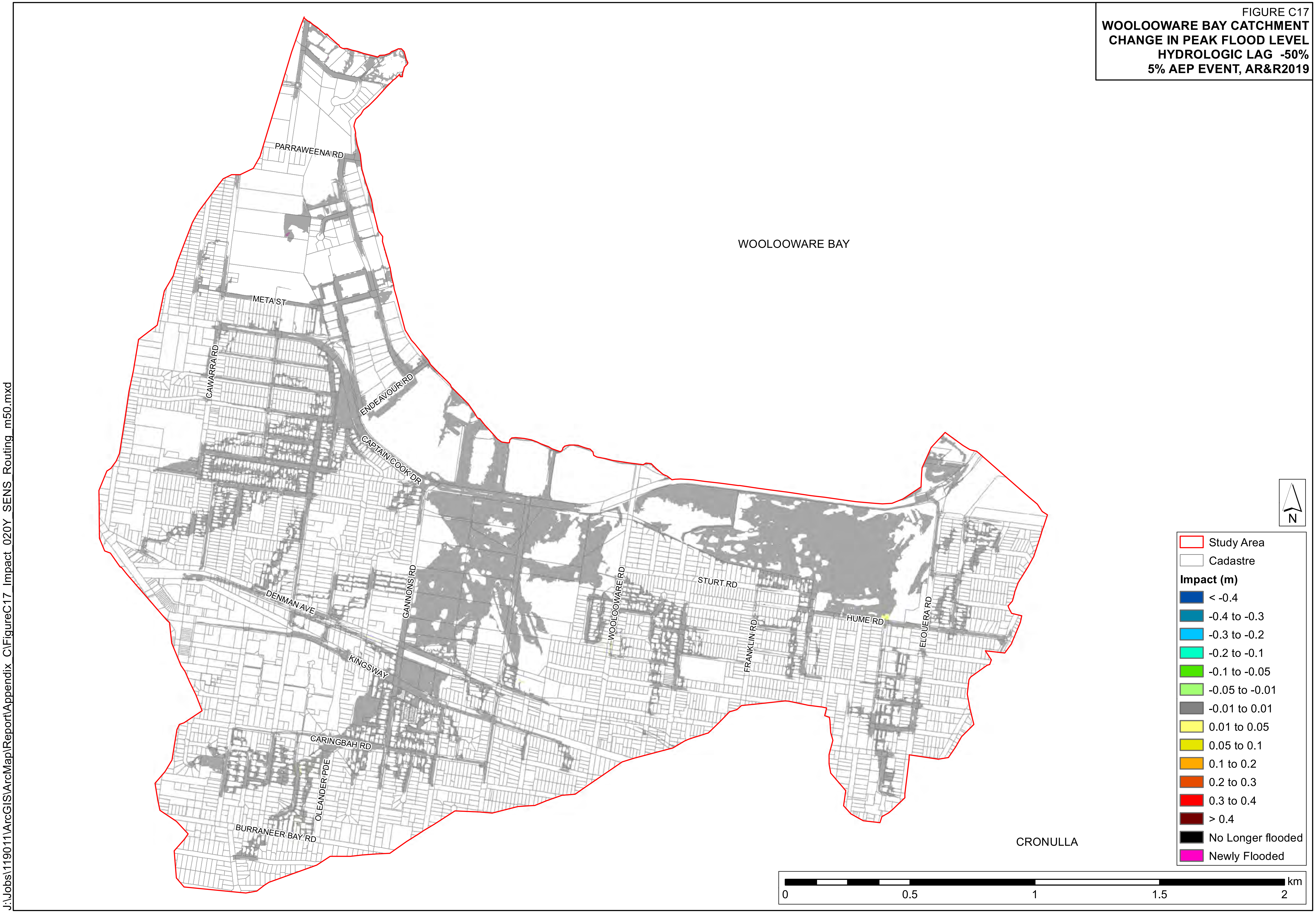


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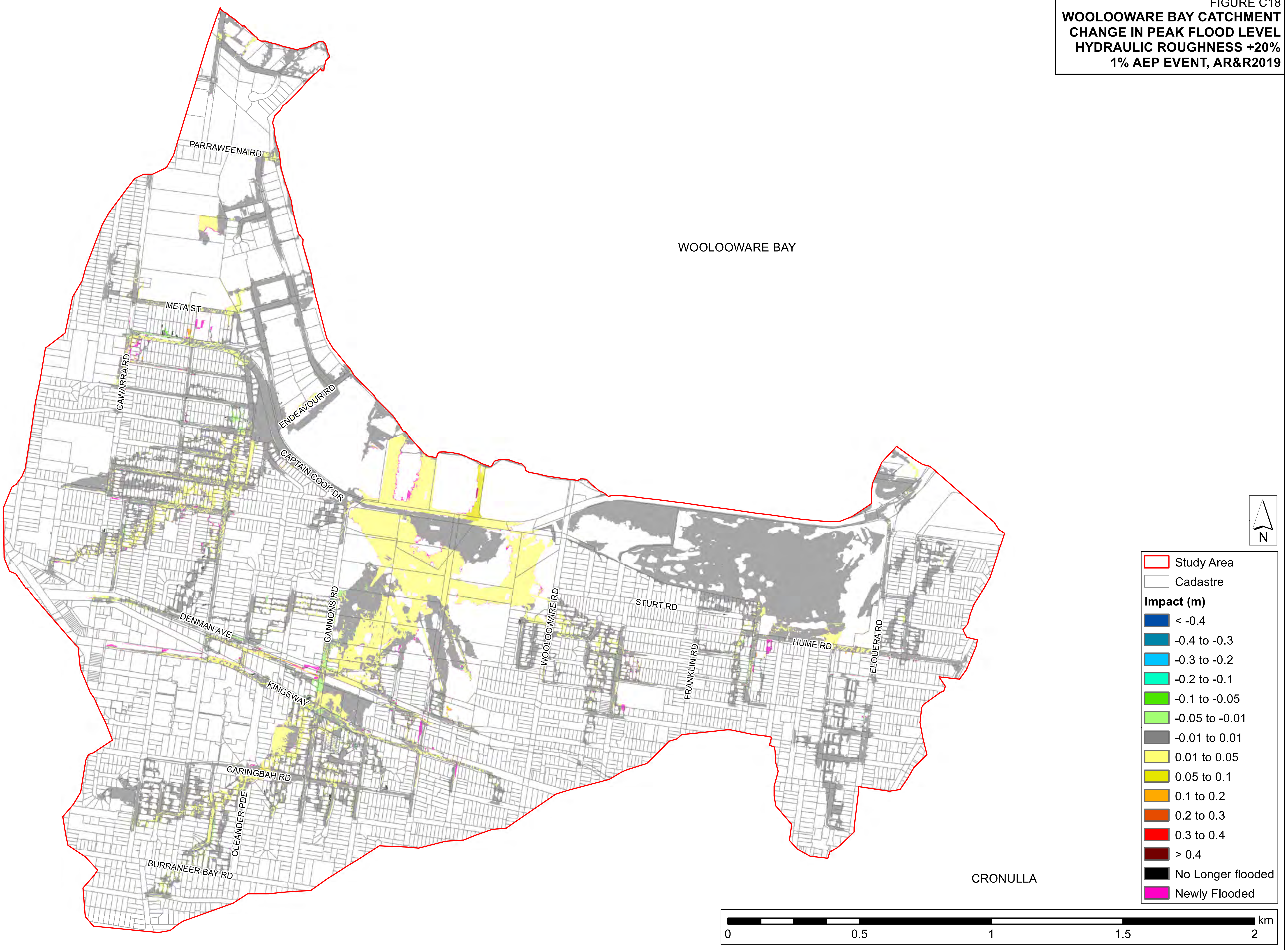
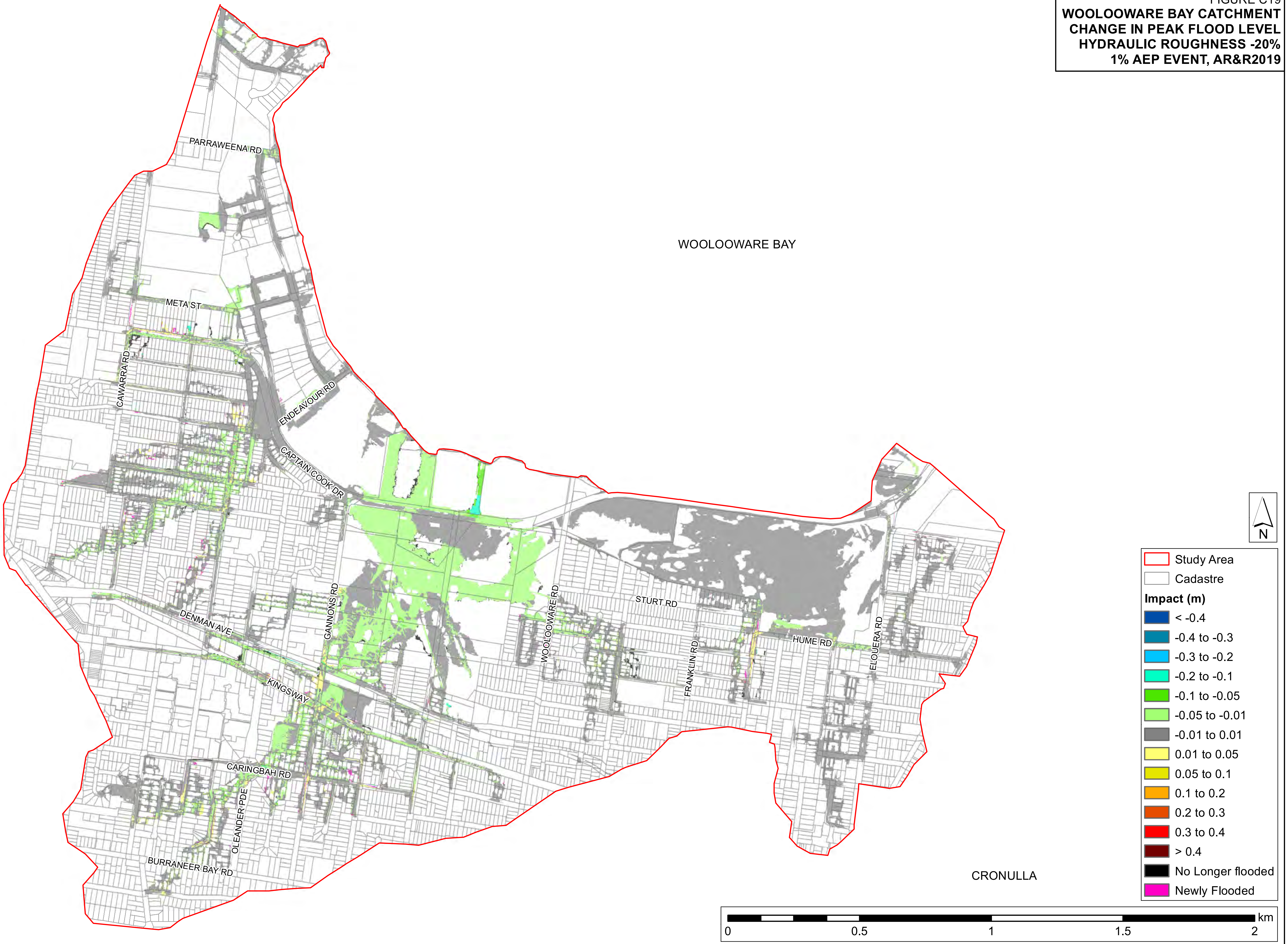
FIGURE C18
WOOLOOWARE BAY CATCHMENT CHANGE IN PEAK FLOOD LEVEL HYDRAULIC ROUGHNESS +20% 1% AEP EVENT, AR&R2019



J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix C\FigureC18_Impact_100Y_SENS_Mannings_p20.mxd

FIGURE C19
WOOLOOWARE BAY CATCHMENT CHANGE IN PEAK FLOOD LEVEL HYDRAULIC ROUGHNESS -20% 1% AEP EVENT, AR&R2019



J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix C\FigureC19_Impact_100Y_SENS_Mannings_m20.mxd

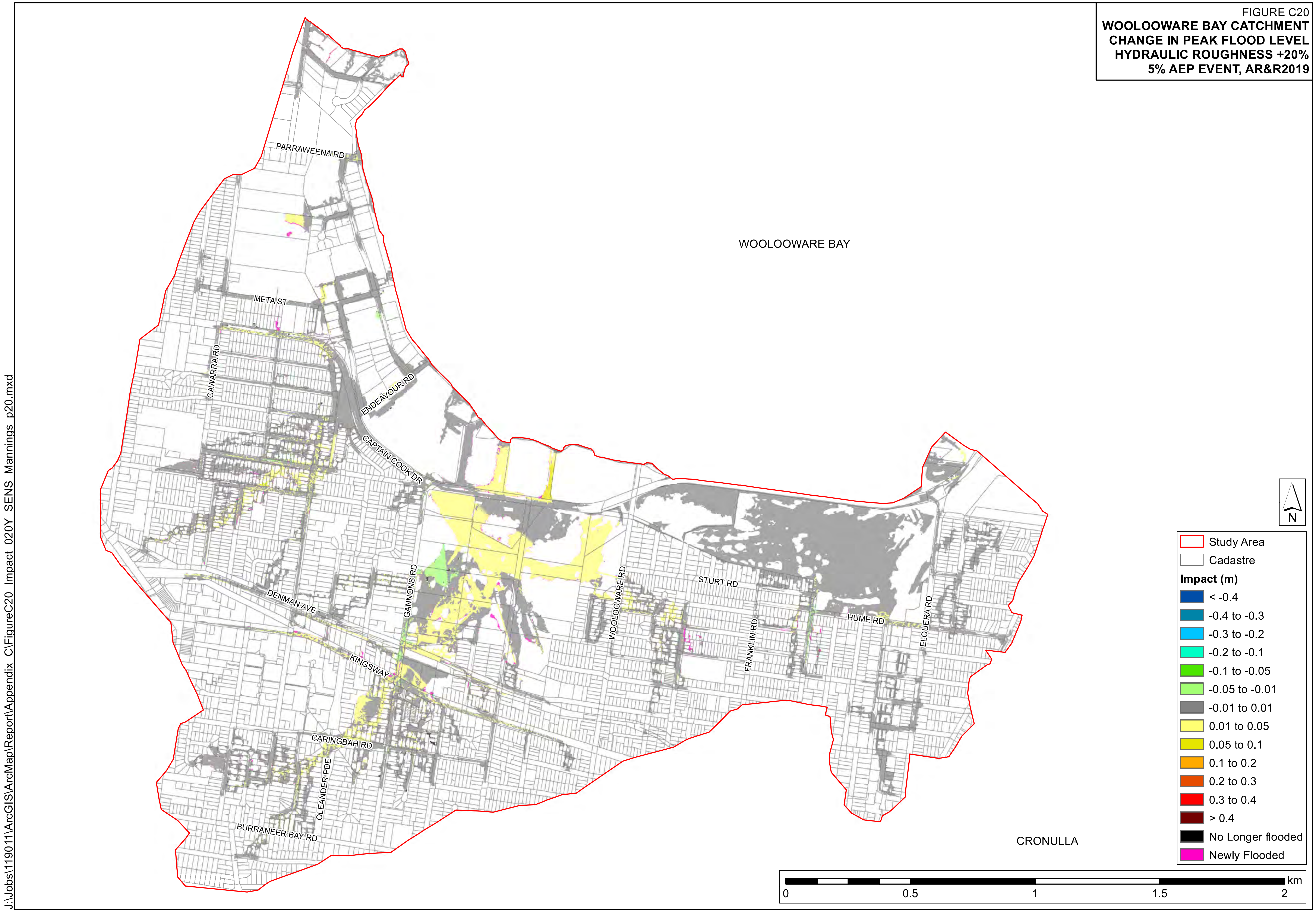


FIGURE C20
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
HYDRAULIC ROUGHNESS +20%
5% AEP EVENT, AR&R2019
WOOLOOWARE BAY
CRONULLA
PARRAWEENA RD
META ST
CAWARRA RD
ENDEAVOUR RD
CAPTAIN COOK DR
DENMAN AVE
GANNONS RD
KINGSWAY
CARINGBAH RD
OLEANDER PDE
BURRANEER BAY RD
WOOLOOWARE RD
STURT RD
FRANKLIN RD
HUME RD
ELOUERA RD
N
Study Area
Cadastre
Impact (m)
< -0.4
-0.4 to -0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
0.3 to 0.4
> 0.4
No Longer flooded
Newly Flooded
0
0.5
1
1.5
2
km
J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix C\FigureC20_Impact_020Y_SENS_Mannings_p20.mxd

FIGURE C21
**WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
HYDRAULIC ROUGHNESS -20%
5% AEP EVENT, AR&R2019**

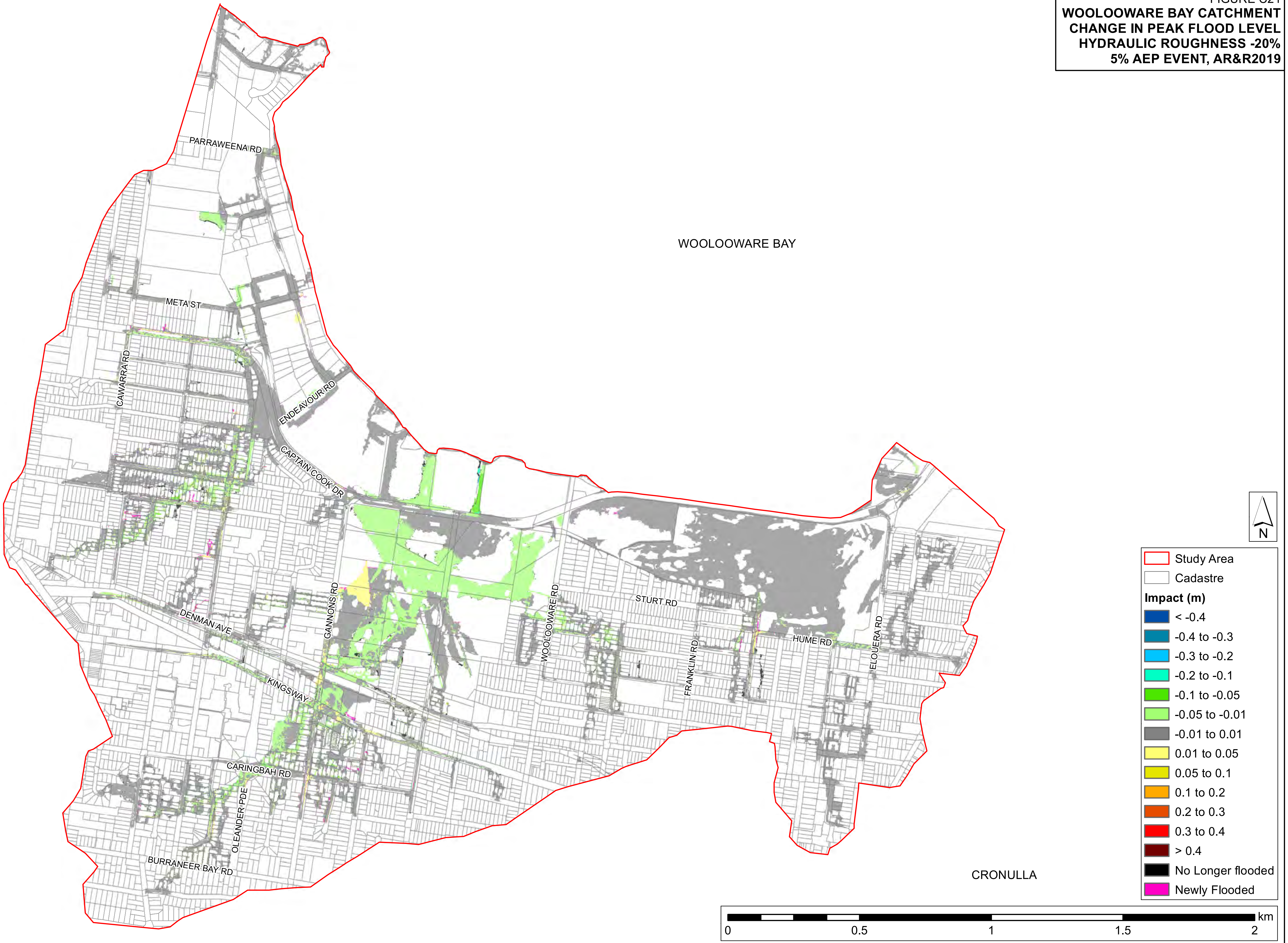


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FIGURE C22
WOOLOOWARE BAY CATCHMENT CHANGE IN PEAK FLOOD LEVEL STORMWATER BLOCKAGE 25% 1% AEP EVENT, AR&R2019

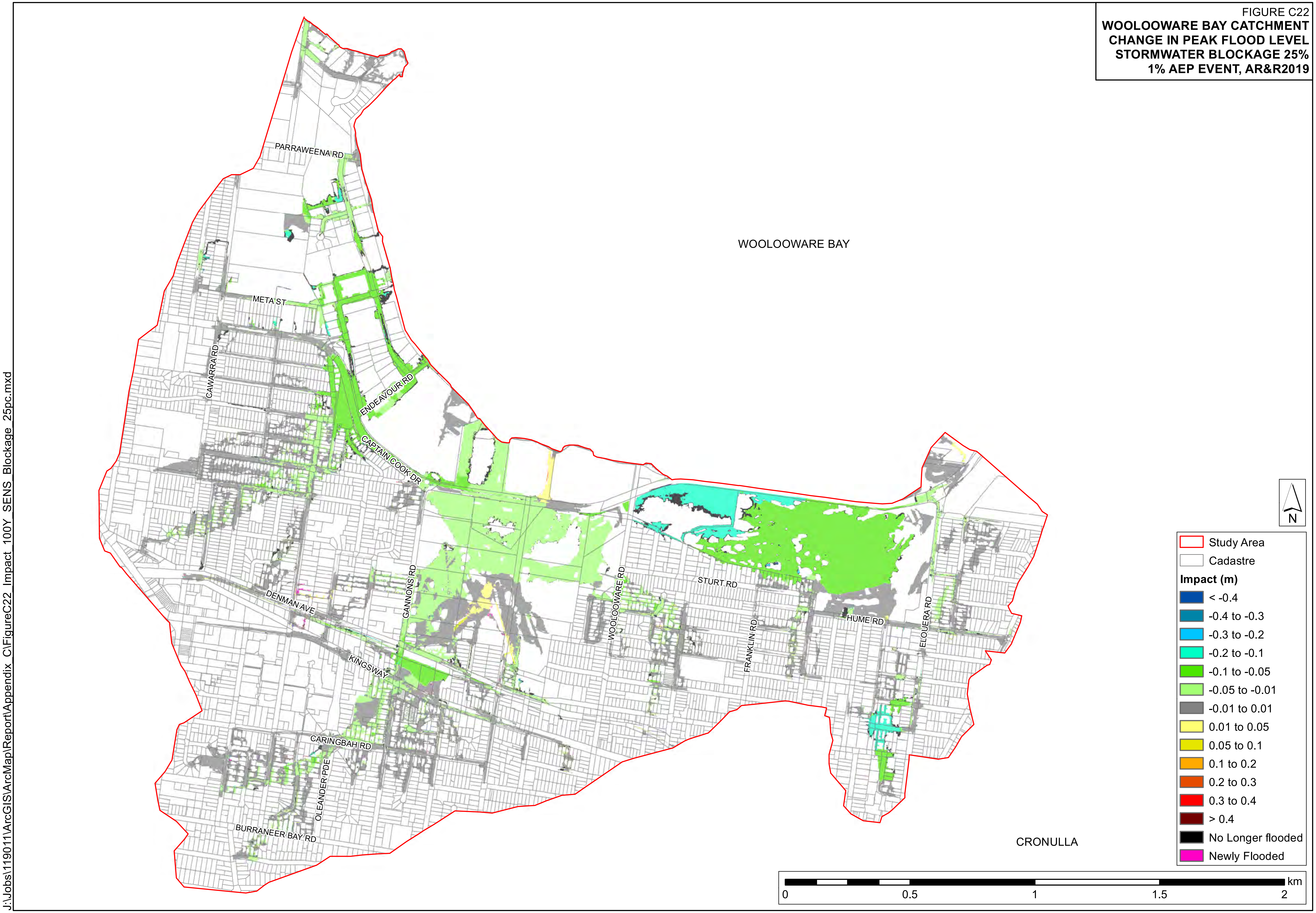

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FIGURE C23
WOOLOOWARE BAY CATCHMENT CHANGE IN PEAK FLOOD LEVEL STORMWATER BLOCKAGE 75% 1% AEP EVENT, AR&R2019

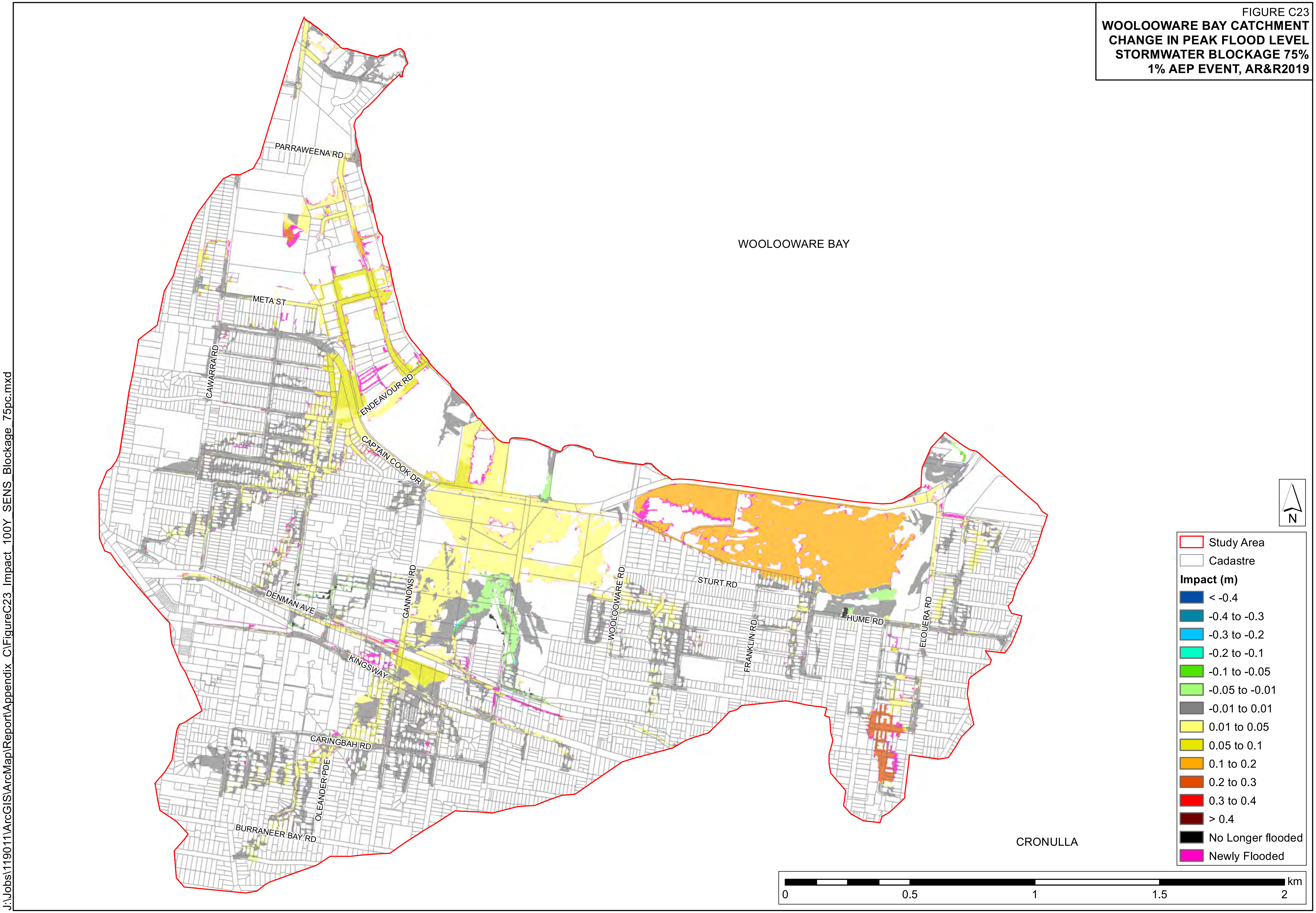

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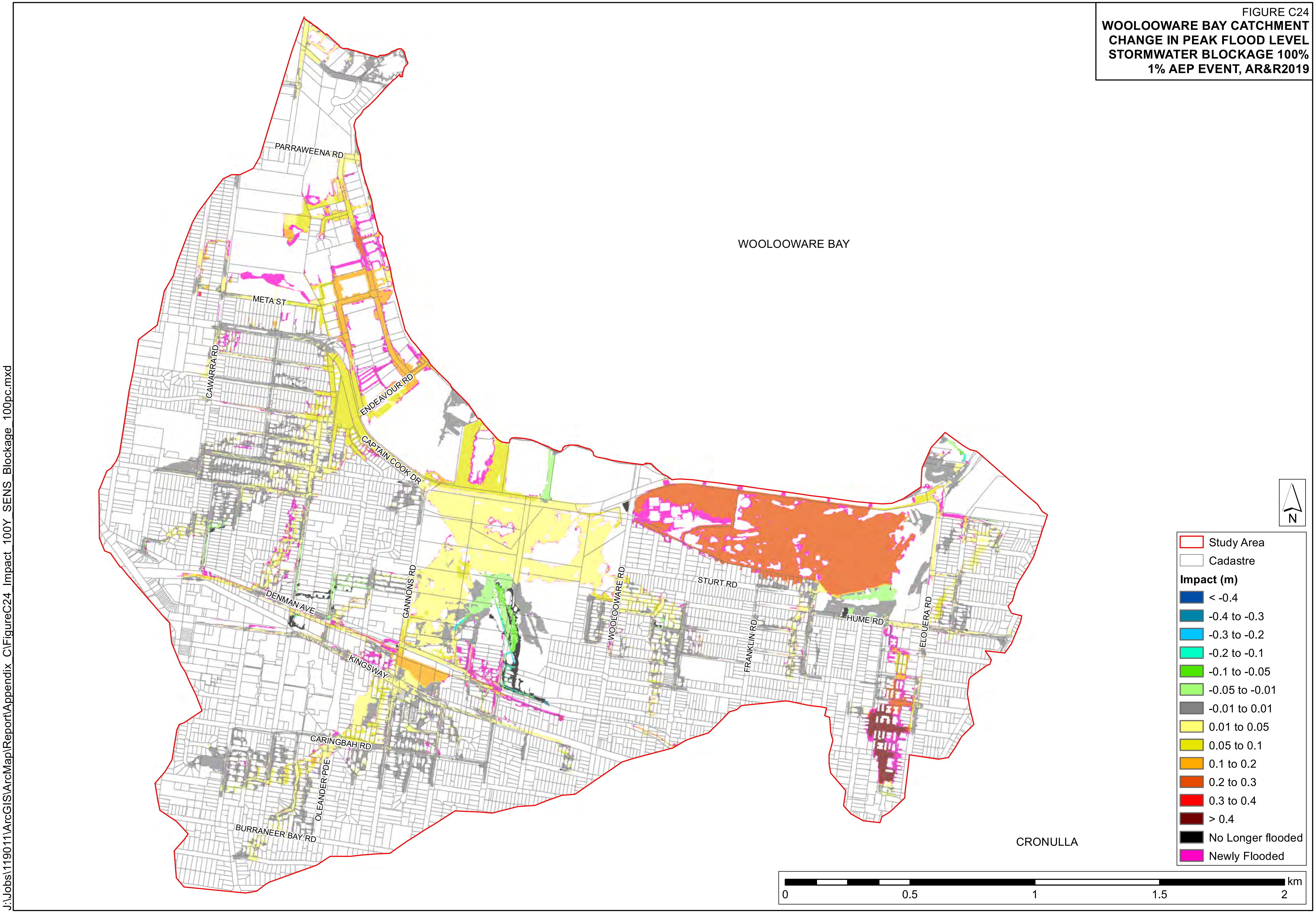
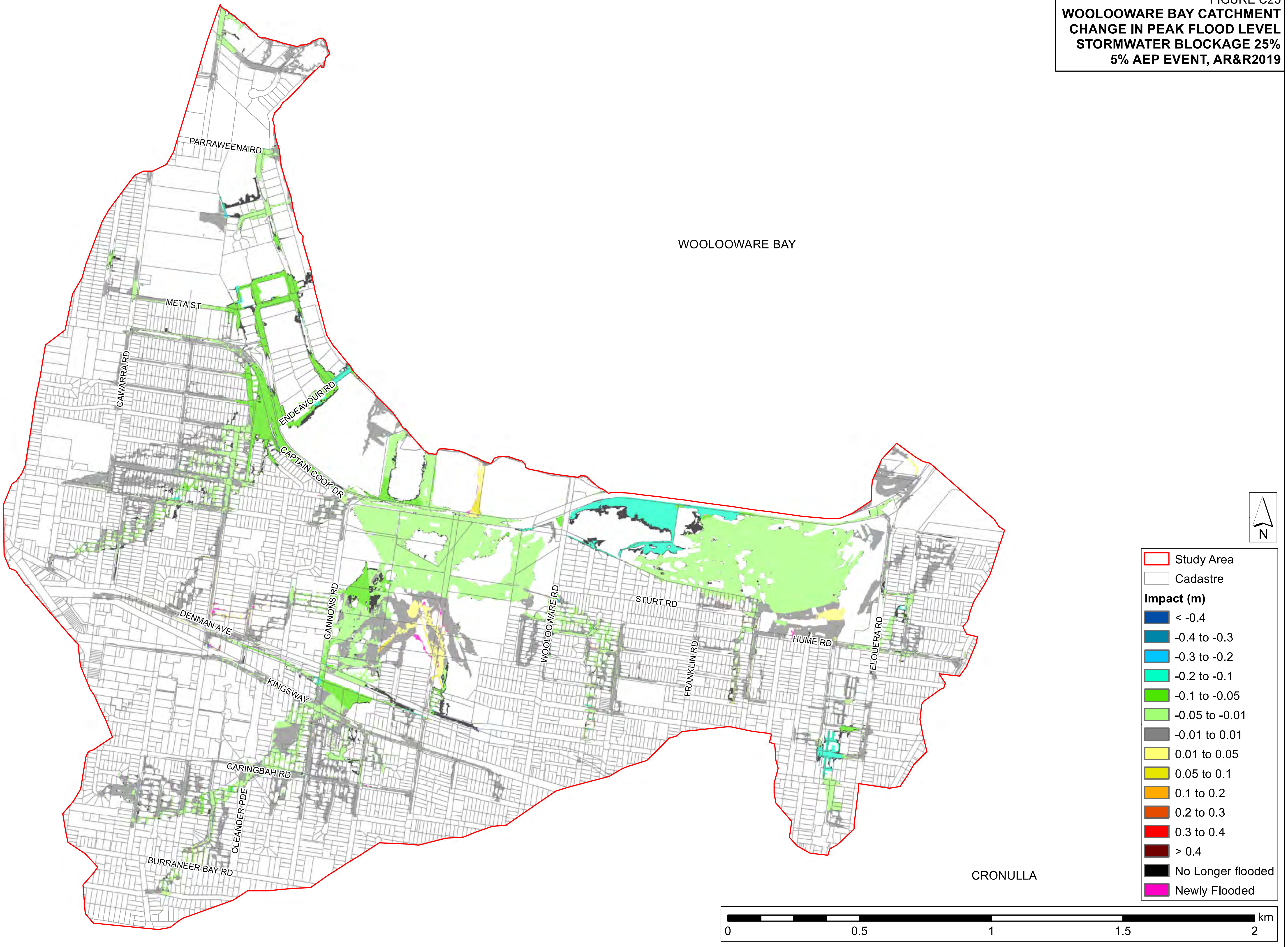
FIGURE C24
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
STORMWATER BLOCKAGE 100%
1% AEP EVENT, AR&R2019



J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix C\FigureC24_Impact_100Y_SENS_Blockage_100pc.mxd

FIGURE C25

WOOLOOWARE BAY CATCHMENT CHANGE IN PEAK FLOOD LEVEL STORMWATER BLOCKAGE 25% 5% AEP EVENT, AR&R2019



J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix C\FigureC25_Impact_020Y_SENS_Blockage_25pc.mxd

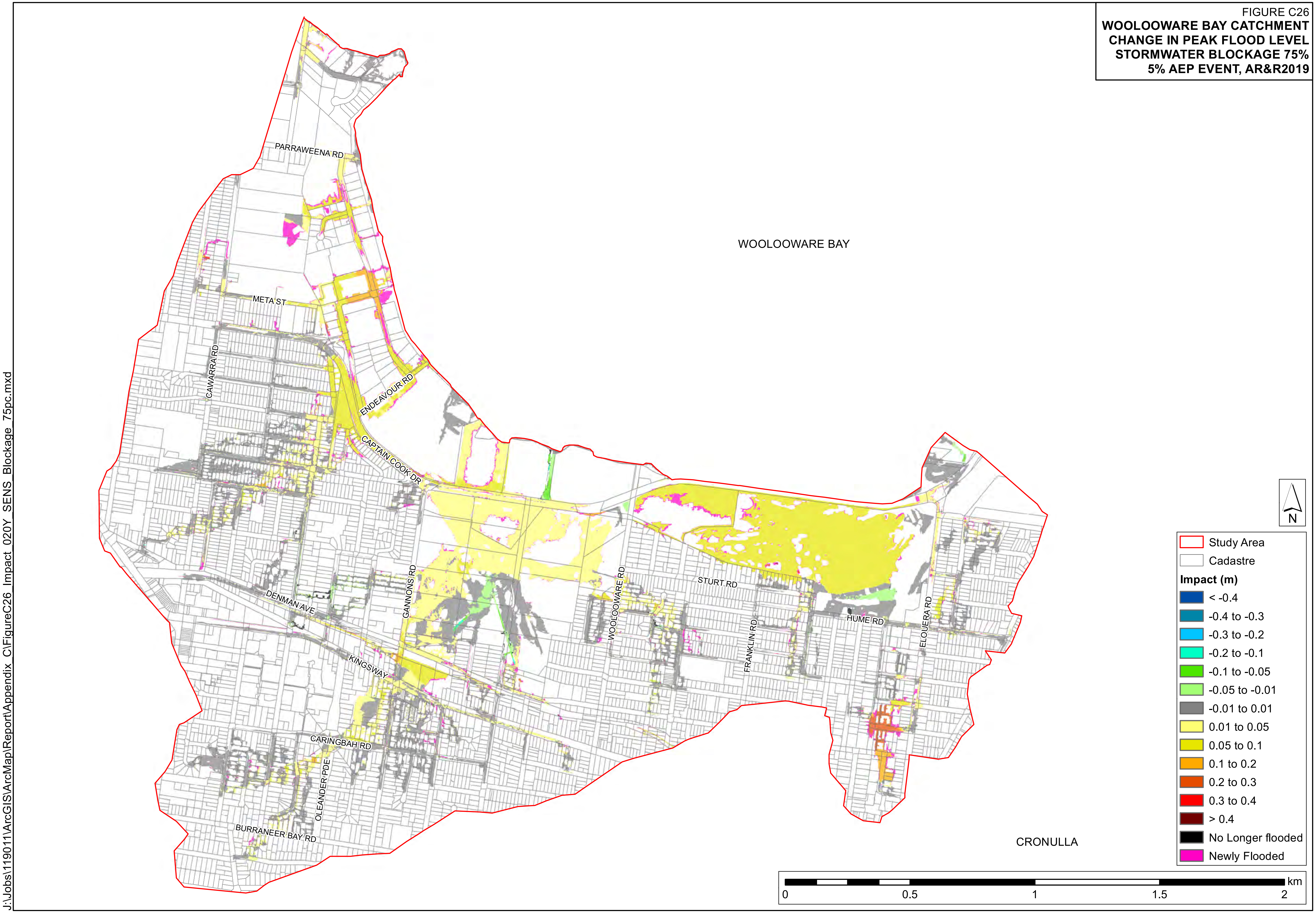
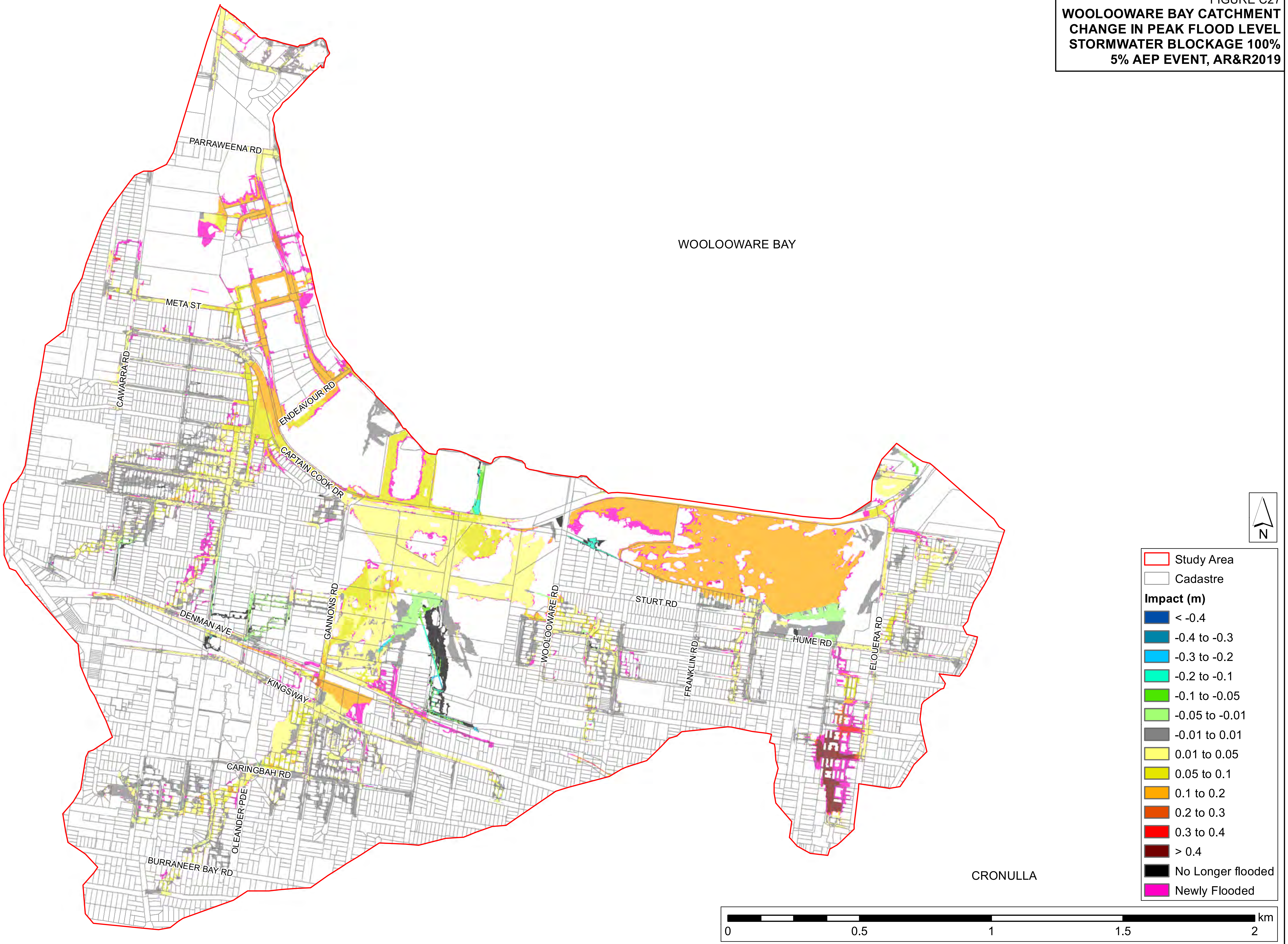


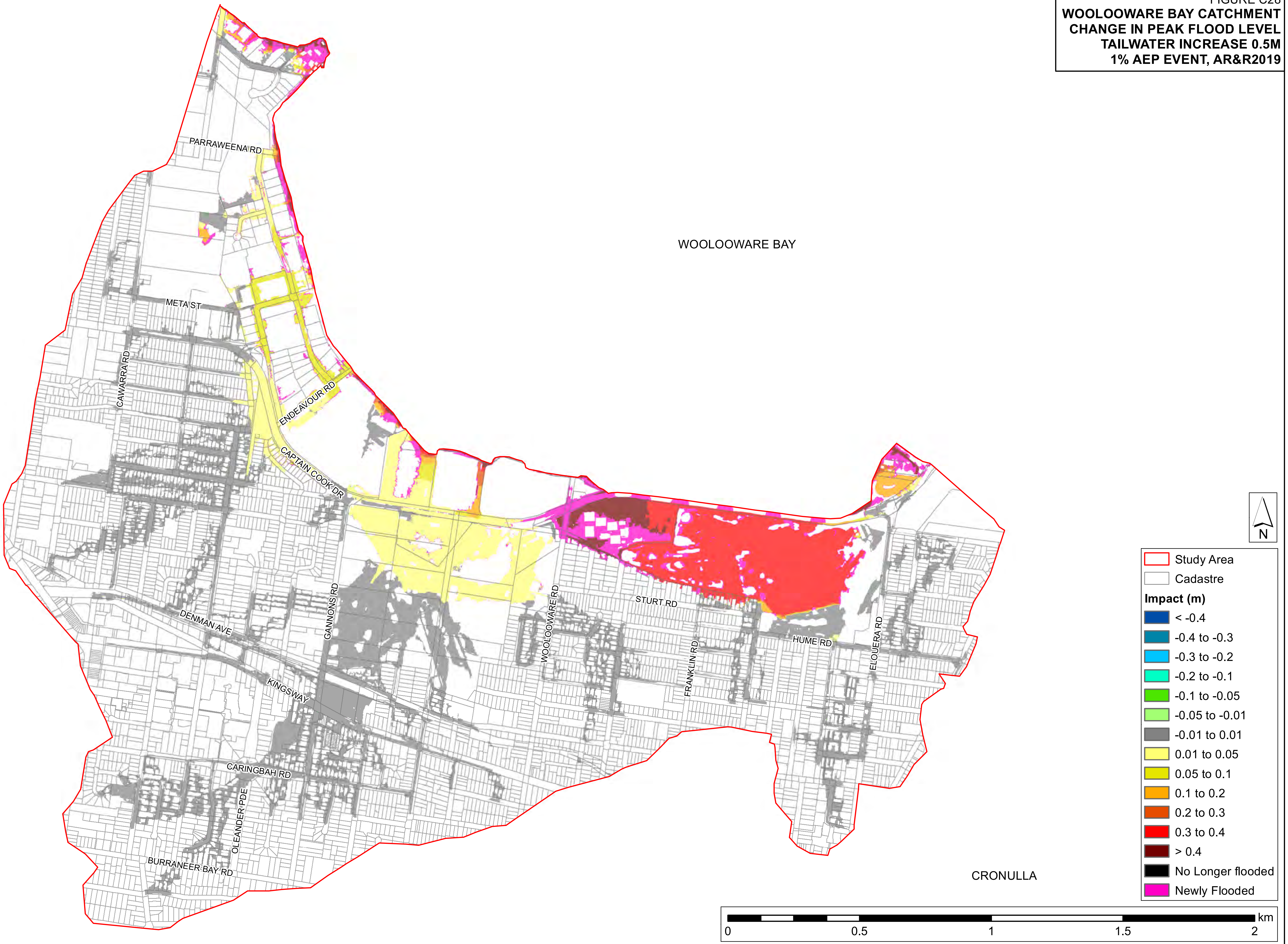
FIGURE C26
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
STORMWATER BLOCKAGE 75%
5% AEP EVENT, AR&R2019
WOOLOOWARE BAY
CRONULLA
PARRAWEENA RD
META ST
CAWARRA RD
ENDEAVOUR RD
CAPTAIN COOK DR
DENMAN AVE
GANNONS RD
KINGSWAY
WOOLOOWARE RD
STURT RD
FRANKLIN RD
HUME RD
ELOUERA RD
CARINGBAH RD
OLEANDER PDE
BURRANEER BAY RD
N
Study Area
Cadastre
Impact (m)
< -0.4
-0.4 to -0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
0.3 to 0.4
> 0.4
No Longer flooded
Newly Flooded
0
0.5
1
1.5
2
km
J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix C\FigureC26 Impact 020Y SENS Blockage 75pc.mxd

FIGURE C27
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
STORMWATER BLOCKAGE 100%
5% AEP EVENT, AR&R2019



J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix C\FigureC27_Impact_020Y_SENS_Blockage_100pc.mxd

FIGURE C28
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
TAILWATER INCREASE 0.5M
1% AEP EVENT, AR&R2019



J:\Jobs\119011\ArcGIS\ArcMap\Report\Appendix C\FigureC28_Impact_100Y_SENS_Tailwater_p500mm.mxd

FIGURE C29
WOOLOOWARE BAY CATCHMENT CHANGE IN PEAK FLOOD LEVEL TAILWATER REDUCTION 0.5M 1% AEP EVENT, AR&R2019

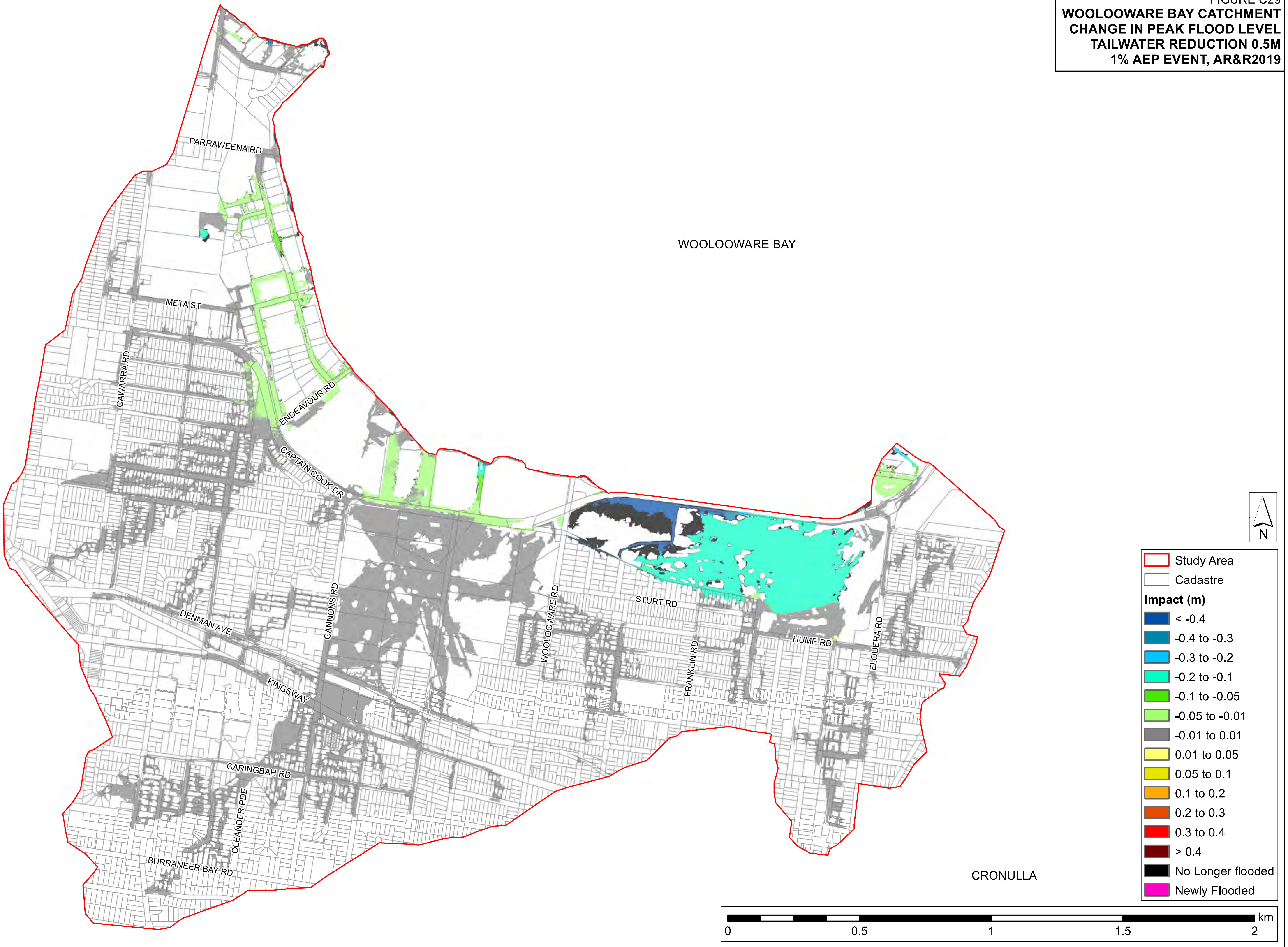


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FIGURE C30
WOOLOOWARE BAY CATCHMENT CHANGE IN PEAK FLOOD LEVEL TAILWATER INCREASE 0.5M 5% AEP EVENT, AR&R2019

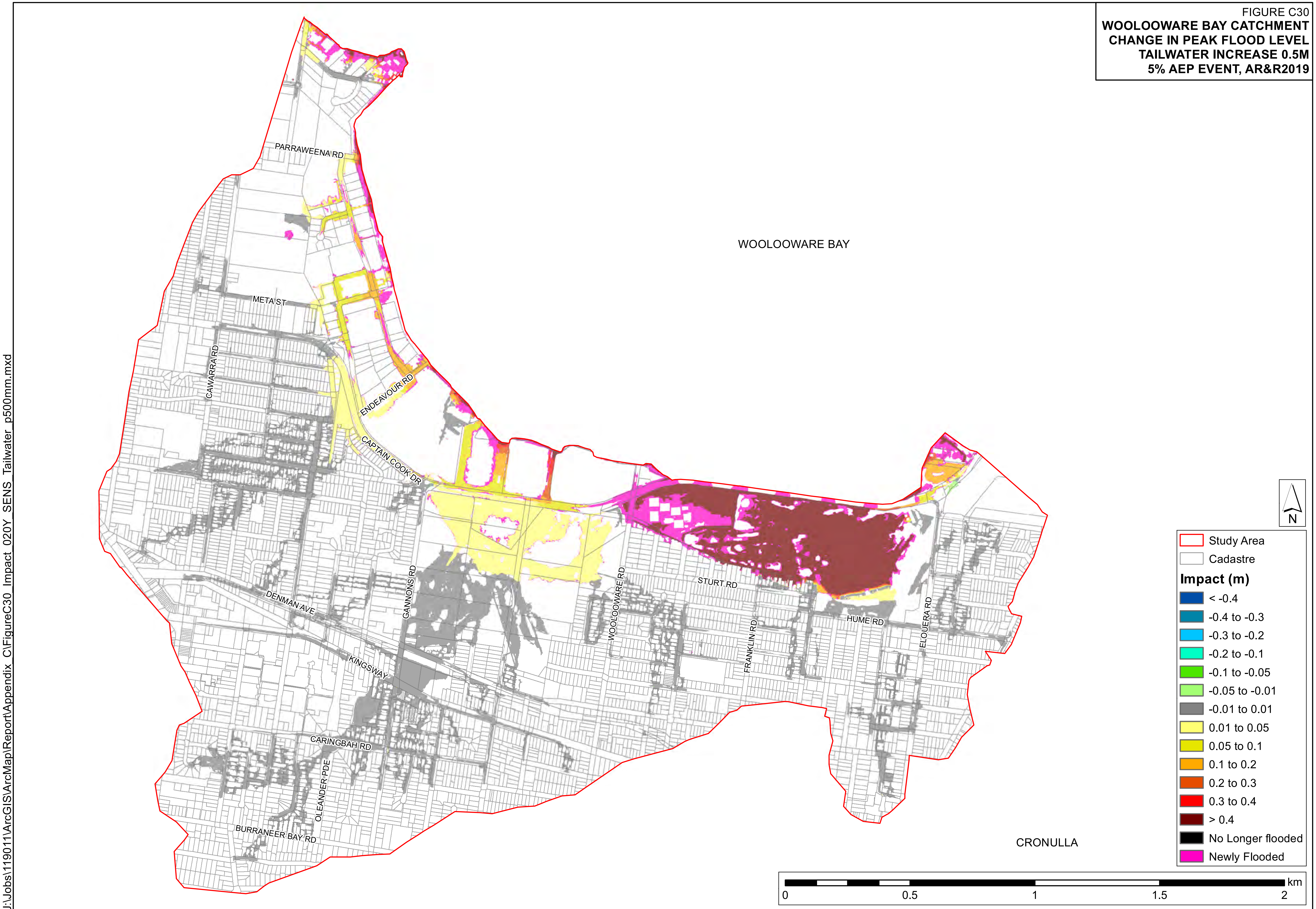
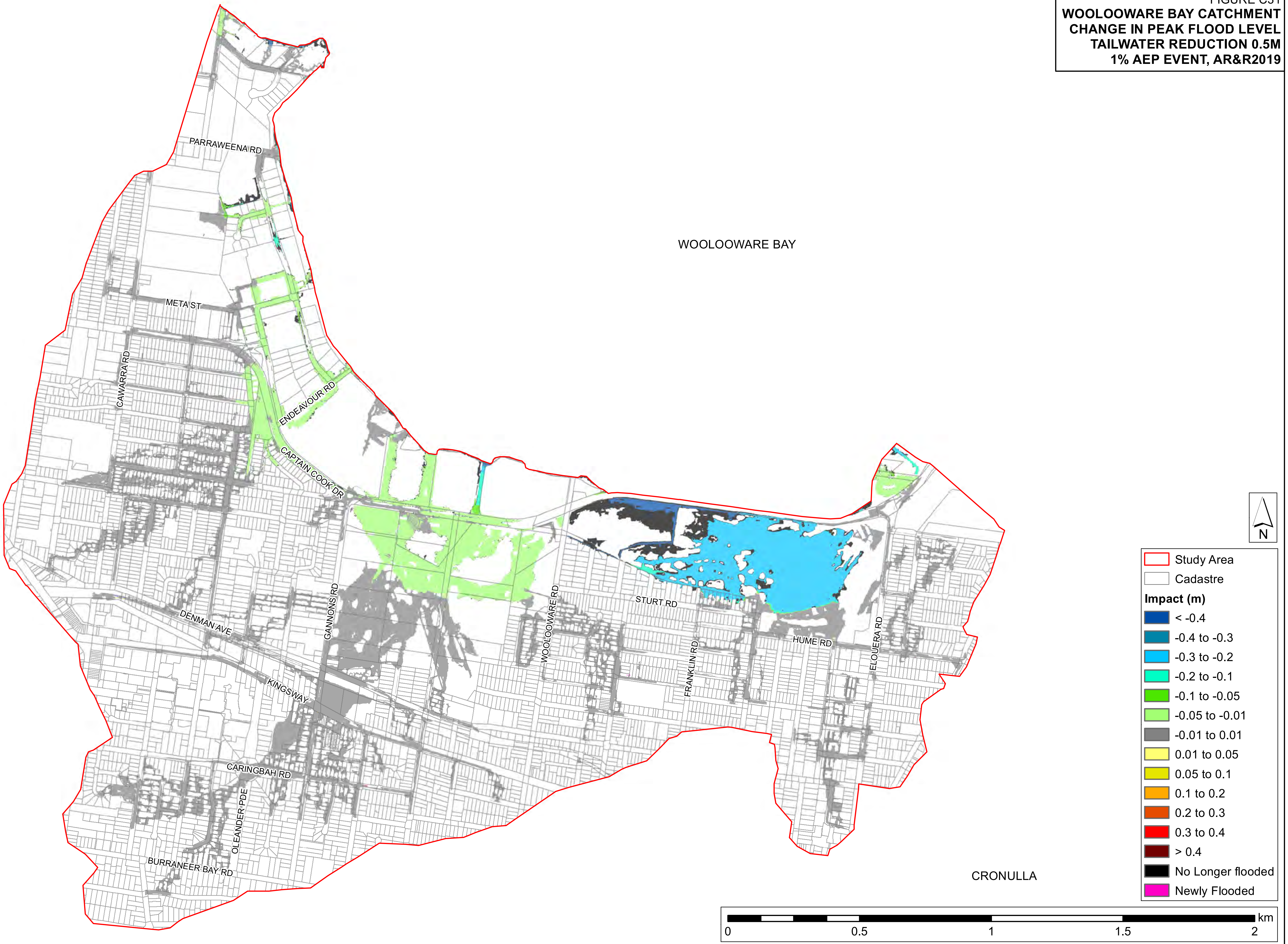


FIGURE C31
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
TAILWATER REDUCTION 0.5M
1% AEP EVENT, AR&R2019



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GLN’s Floodplain Management Planning Considerations

Appendix D

gln.

planning
consulting
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WOOLOOWARE BAY CATCHMENT

Floodplain Risk Management Study & Plan

Planning Considerations

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Floodplain Risk Management Study & Plan

Woolooware Bay Catchment, Sutherland Shire Council

Prepared for

WMA Water
on behalf of Sutherland Shire Council

By

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1 Introduction

WMA Water (**WMA**) has engaged GLN Planning (**GLN**) to provide town planning input into the preparation of the Woolooware Bay Catchment Floodplain Risk Management Study and Floodplain Risk Management Plan (**FRMS&P**) being prepared on behalf of Sutherland Shire Council (**Council**). The FRMS&P are supported by funding from the NSW Governments Floodplain Management Program administered by the Department of Planning, Industry and Environment (**DPIE**).

The brief was comprised of both standard DPIE brief requirements and a range of additional matters identified by Council for consideration[1]. The following is a composite of the land use planning matters required to be addressed:

- Describe and examine the FRM process in NSW
- The consistency of current or proposed future strategic planning directions for the community in relation to addressing floodplain management objectives
- The adequacy of current land use planning and building controls for specific development areas or developments in relation to addressing floodplain management objectives and managing flood risk to both new development and limiting impacts upon the existing community
- The suitability of different land uses in different areas of the floodplain considering their use and community response to flooding
- The suitability of different land uses in different areas of the floodplain, considering the vulnerability of these uses and their users to flooding
- The selection of appropriate flood planning levels (**FPL**s), inconsistencies with the use of a singular FPL in the local environmental plan (**LEP**) and development control plan (**DCP**), and related terminology used in the DCP.
- The DCP FRM provisions including the application of flood risk precinct in the DCP and consideration of the use of flood planning constraints categories[2] (**FPCC**) approach, and the potential use of guidance notes to supplement the DCP.
- Opportunities for refining the use of restrictive covenants
- The process for fence approvals that impact on flooding and consider potential voluntary fence modification schemes
- The residual flood risk, following the instigation of general constraints and in relation to the need for additional constraints, where warranted, in specific areas of the floodplain

[1] These additional considerations were outlined within Appendix A of the brief.

[2] As outlined by the *Guideline 7-5 Flood Information to Support Land-use Planning* which is a supporting document for *Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (Australian Institute of Disaster Resilience – AIDR, 2017)

- Analysis of both user and stakeholder needs
- Provide recommendations for changes in land use planning directions or controls to address any identified shortcomings
- Provide recommendations for planning instruments or alternate development controls to reduce the impacts of development on flooding and flood impacts on new development.

In addition to the above, on 14 July, DPIE implemented a range of changes to FRM provisions of LEPs and associated changes to the *Environmental Planning and Assessment Regulation 2000*, together with introducing a new Flood Planning Guideline[3]. Our brief was extended to take into consideration these changes. Additionally. there have been other document updates and changes between the preparation of our draft and final reports which have been taken into consideration.

In order to address the above matters, we outline the planning context for the study area, focusing on aspects that are specifically relevant to flood risk management (**FRM**). While the FRMS&P relates to a part of the local government area (**LGA**) it is important for recommendations regarding the preparation of planning controls to be structured so that they can also be easily applied to other floodplains in the LGA.

[3] These changes were collectively referred to as the Flood Prone Lands Package and were communicated to Councils by a DPIE Planning Systems Circular PS 21-006 dated 14.07.2021.

2 Purpose of Report

2.1 The Role of Planning in Flood Risk Management

The key benefits that planning can provide within the suite of strategies delivered by an FRMS&P are:

- providing guidance at the strategic planning stage as to where different types of development should occur based on FRM considerations, with regard to potential and acceptable mitigation options

- providing development controls to minimise the risk to people, private property and public infrastructure where development is planned to occur within the floodplain

- ensure that the communication of flood risk, as may be interpreted by the community through planning documents, is easily understood and cannot be misinterpreted. Planning documents typically deal with where flood related planning controls apply rather than where flood risks apply.

While flood risk management can be relevant to the preparation of a plan for an area or in the assessment of a development application (**DA**), there will also be other non-FRM considerations that will be relevant. FRM will ultimately need to be weighed with other planning considerations to achieve balanced outcomes that meet community expectations.

Despite this, there are baseline standards or community expectations relating to safety, exposure of property and infrastructure to costly repairs and avoidance of disruption to the occupation of homes and the operation of businesses, that should be considered when making planning decisions.

2.2 Objectives of this report

The objectives for this report are to:

- outline and review the state and local planning policy context (including existing environmental planning polices and instruments and long term planning strategies for the area)

- identify existing FRM related planning issues

- discuss options to address these planning issues

- make recommendations for incorporation into the FRMS&P.

The planning recommendations for the Woolooware Bay Catchment FRMS&P will focus on providing advice to Council on changes that can be made to the planning controls to better achieve development that minimises flood risks to as low as reasonably and practically achievable. Advice will also be provided on principles to be applied when considering changes to land use zoning plans and the presentation of planning information, including flood maps prepared for planning purposes.

While this FRM&P relates to only a part of the LGA that is mainly subject to overland flow flooding, it will be important to establish a framework for input to strategic planning, planning controls and flood planning maps that can be easily applied to other floodplains in the LGA, including where riverine flooding is the primary consideration.

2.3 Other Studies

We have referenced the following FRMS&Ps and related studies (**Table 1**).

Table 1: Previous Relevant FRM Investigations

Study Name	Author	Year
Bundeena Flood Management Study	Kinhill	1993
Bundeena Creek Flood Study	Worley Parsons	2014
Deadmans Creek Flood Study	NSW Dept of Land & Water Conservation	1997
Ewey Creek Management Plan	Clouston + Willing & Partners + Ian Perkins	1993
Georges River Floodplain Risk Management Study & Plan	Bewsher	2004
Gwawley Bay Catchment Flood Study	Bewsher/ FloodMit	2012
Initial Subjective Assessment of Major Flooding	Bewsher	2004
Kurnell Township Flood Study	WMA Water	2009
Woolooware Bay Catchment Flood Study	WMA Water	2014
Woolooware Golf Course – review of drainage issues	WMA Water	2013
Woolooware Bay Topographic Survey	Peter Bolan & Associates Pty Ltd	2012
Sea Level Risk Rise Assessment	GHD	2011
Lower Georges River FRMS	Bewsher	2011
Initial Assessment of Major Flooding	Bewsher	2004
Lower Georges River Stormwater Management Plan	NSW EPA	1999

In addition to comments directly provided by Council, the above studies and plans provide context to the types of FRM issues that might need to be addressed in reviewing Councils FRM planning framework. Key observations include:

- The 2004 Georges River FRMS&P provided the basis for Council's current FRM planning controls. These were developed 15 years ago and are due for updating. They were also prepared for a specific riverine flooding context and not overland flow flooding.

- Substantial parts of the LGA are affected by overland flow flooding. Within these areas there are variable impacts associated with buildings and other structures such as fences that may have historically been located within or near an overland flow path, or possibly have recently escaped the scrutiny of planning approval processes. These structures can change flood behaviour causing additional impacts on others in the floodplain, and are typically associated with land uses that are directly affected by flooding. Blockages in culverts and channels caused by debris washed in during a flood can also change flood behaviour in ways that are difficult to predict.

- Some development in the LGA is located in low lying areas close to the coast. The flood risks in these areas can be compounded by the potential influence of high ocean levels. The predicted increase in sea levels associated with climate change can further increase flood impacts and introduce the potential for coastal accretion and permanent inundation. While sea level rise is accounted for in existing design floor levels, issues arise with ground levels (eg private open space, and public domain areas) which cannot be easily raised or defended.

- Roads which potentially provide the sole evacuation route during major floods can be cut off. In the study area this periodically manifests with the closure of Captain Cook Drive during floods causing traffic management issues. This also constrains the possibility of evacuating out of some flood affected areas, particular those subject to flash flooding where warning times are non-existent or ineffectual.

- Flood levels derived from flood studies and the general understanding of flood risks have been continuously adjusted over time. This has been because of factors such as improved flood models, more accurate terrain data, changes in climate change predictions, and changes in the extent and nature of development.

- After a period of use, it is now opportune to review relevant FRM planning controls to improve clarity and useability, address any apparent inconsistencies such as having one FPL in the LEP and multiple FPLs in the DCP, clarify flood impact and cumulative impact assessments, rationalise flood mapping used for planning purposes and to consider any additional peripheral matters such as use of restrictive covenants and innovative approaches to managing fencing.

- As a broader objective Council has initiated some projects aimed at reinstating the natural ecological system and appearance of creek corridors. Watercourse rehabilitation can contribute to reducing sediment loads and the risk of downstream culvert or channel blockages.

Consequently, a planning framework to improve the way FRM is addressed will need to cope with:

- A complexity of policy and practice as to how to structure Council's principal planning policy documents (local environmental plan and development control plan).

- Different types of flooding (i.e. riverine and overland flow flooding).

- Ability to allow for adjustments over time as predictions of flood behaviour change due to refined modelling, climate change and new development.

- Providing mechanisms to manage minor development that are superficially low impact (such as fences sheds and small extensions) that normally escape detail assessment, but can have significant effects on overland flood behaviour.

- Determining how planning can support ongoing emergency management that might be relevant to flood affected development (e.g. requiring PMF refuges for shelter in place and encouraging individual flood emergency response plans) given short or non-existent warning times in some areas.

- How to communicate the varying types of flooding, and required responses, from the community, to contribute to awareness and resilience – and how not to miscommunicate these flood risks through the planning system.

- Providing planning recommendations that manage where different types of development should not be located and, where permitted, the type of controls that should be imposed having regard to historically derived approaches that the community is accustomed to versus what might be considered current best practice.

- Managing the environmental quality and functioning of waterway systems consistent with FRM objectives.

- Providing approval pathways for development that are fit for purpose, i.e. allowing minor development to follow an exempt or complying development approval pathway or requiring more documentation for a full DA assessment. The approval process should not unnecessarily burden Council or applicants if it is unlikely to provide a different FRM outcome.

In addition, Council has produced several strategic planning documents (see **Table 2**) that contribute to an understanding of how FRM has been addressed to date and the existing and future economic, social and environmental characteristics of the study area. Council has a commitment towards maintaining the environmental and scenic quality of waterways and balancing urban growth with the environmental and infrastructure capacity of the area.

Table 2: Strategic Planning Studies

Study Name	Author	Date
Delivery Program and Operational Plan 2017-2021	Sutherland Shire Council	June 2018
Community Strategic Plan	Sutherland Shire Council	2017
Environment Strategy	Sutherland Shire Council	January 2013
Environment and Sustainability Strategy	Sutherland Shire Council	2011/2012

Council has also provided a list of example DAs with flooding issues encountered during the assessment process, summarised in **Appendix A**. The issues arising related mainly to:

- insufficient information being submitted with the DA. While this is a common issue associated with DAs in general, better guidance as to where flood issues exist and the type of information required (such as advisory guidelines prepared to complement the DCP) to address such issues could assist in managing this problem.

- detail design considerations that arose because of difficulties in addressing prescriptive controls due to site or development specific issues. These issues appear to have been ultimately resolved but it is expected that clear performance based development controls will assist both applicant's and Council officers in determining what deviations from prescriptive controls would be acceptable.

This report will have regard to above studies and context.

3 Study Area

3.1 Physical Setting

The Woolooware Bay Catchment encompasses an area of over 6km^2 and drains to Woolooware Bay. The Woolooware Bay Catchment is located towards the north-eastern end of the urbanised area of the Shire (**Figure 1**). The catchment rises in Caringbah South at a maximum elevation of 62 m AHD and slopes gradually in a northerly direction towards the flat, low-lying foreshore area of Woolooware Bay. The catchment is affected by overland flood flooding similar to many other low-lying urbanised coastal catchments.

The study area comprises parts of the suburbs of Caringbah, Caringbah South, Woolooware and Cronulla.

Figure 1: Woolooware Bay FRMS&P Catchment

Land use in the catchment is predominantly low-density residential but with commercial and light industrial development concentrated in the north of the catchment. The lower reaches of the catchment contain large areas of recreational open space, including Woolooware and Cronulla Golf Courses, Solander Playing Fields and Endeavour Field (Shark Park), that were mostly established on reclaimed, tidally-affected, land.

New residential development is underway in the north-eastern extent of the catchment within the Greenhills Beach area. Only a small part of this new residential area, zoned E4 Environmental Living, is within the study area.

Other parts of the catchment have seen an upzoning to support increased residential development intensity. In particular, the northern extent of the Cronulla residential area was rezoned from R2 Low Density Residential to R3 Medium Density Residential around 4 years ago. Sporadic redevelopment is also ongoing throughout the study area (and LGA).

Figure 2 shows the general land use zoning pattern across the Woolooware Bay Catchment.

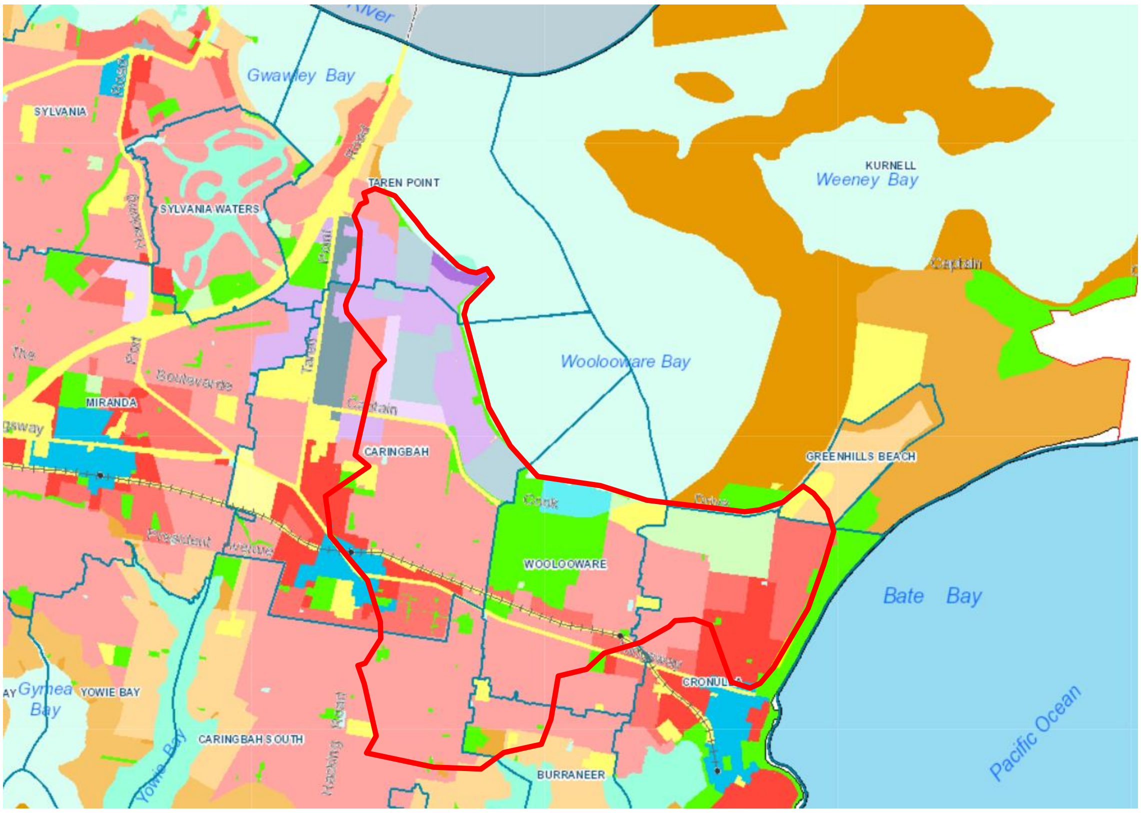

Figure 2: General Land Use Zones Across the Catchment

Captain Cook Drive, the Kingsway and the Illawarra Railway line are the major transport routes that traverse the catchment in an east-west direction. The catchment is serviced primarily by a stormwater pit and pipe network although there are several open channels in the lower catchment. Some of this network passes across private property, but is not always within dedicated drainage easements.

There are three major sub-catchments that drain towards Cronulla Golf Course, Woolooware Golf Course and Endeavour Road, Caringbah.

The study area excludes the commercial and light industrial area within Taren Point that drains northwards to Woolooware Bay via the Production Road stormwater channel. This area was investigated as part of the 2012 Gwawley Bay Catchment Flood Study and 2015 Gwawley Bay Catchment FRMS&P.

3.2 Population Characteristics

Characteristics of the permanent population of the area, that could be relevant to assessing flood risk, can be drawn from various sources (mainly the 2016 Census). While this data is primarily relevant to emergency management, it also assists in understanding the socio-economic nature of the community to be weighed up when deciding on FRM recommendations and tailoring flood education programs. These characteristics include:

- The population of the Sutherland LGA was 218,464, based on usual place of residence.
- The populations of the suburbs within the Woolooware Bay catchment are:
  - Caringbah: 11,658
  - Caringbah South: 12,242
  - Woolooware: 3,962
  - Cronulla: 18,070.
- The median age in the LGA was 40, being slightly higher than the Australian median age of 38. The median age varies across the study area from 37 in Caringbah to 42 in Caringbah South. Just over 22% of the LGA population is aged 60 or over.
- The percentage of the population in the LGA that owned their home with a mortgage was 38.7%, rented was 21.1% and 37.3% were owned outright (compared to 32.2% in NSW).
- 91.7% of dwellings in the LGA had one or more motor vehicle (compared to 87.1% for NSW). The remainder had no motor vehicles, or the number was unstated.
- In the Sutherland LGA, 83.1% of people only spoke English at home, compared to 68.5% in NSW. Other languages spoken at home included Greek 1.9%, Mandarin 1.4%, Cantonese 1.0%, Arabic 0.9% and Italian 0.8%.
- In the LGA, 87.8% of households had at least one person with access to the internet from the dwelling, compared to 82.5% in NSW. This could have been through a desktop/laptop computer, mobile or smart phone, tablet, music or video player, gaming console, smart TV or any other device.
- The most common occupations in the LGA included professionals 24.0%, clerical and administrative workers 16.7%, managers 15.0%, technicians and trades workers 13.5%, and community and personal service workers 10.5%.
- 4.3% of persons in the LGA (compared to 5.4% in NSW) recorded needing assistance with core activities. This relates to people with a profound or severe disability are defined as those people "…needing help or assistance in one or more of the three core activity areas of self-care, mobility and communication, because of a disability, long-term health condition (lasting six months or more) or old age."

In summary, the population of the LGA and study area in general is expected to have a slightly high proportion of persons in older age groups, with relatively low proportions requiring assistance with core activities or residing in households with no cars or internet. Most persons (if not all) are competent English speakers.

3.3 Economic Base

The top 5 industries with registered businesses in the Sutherland LGA (ABS 8165.0 - Counts of Australian Businesses, including Entries and Exits, June 2014 to June 2018) are:

- Construction (21%)
- Professional, scientific and technical services (14.4%)
- Rental, hiring and real estate services (12.3%)
- Financial and Insurance services (10.2%)
- Transport, postal and warehousing (5.7%)

The 2016 Census shows that the fields of occupation in the LGA was dominated by Professionals (20.8%) and Clerical and administrative workers (13.8%), followed by a variation including Technicians and trade workers (13.7%), Community and personal service workers (13.5%), Sales workers (12.9%), and Managers (12%). Approximately 70% residents within the workforce live and work in the LGA and 31% of workers reside outside of the LGA.

The majority of employment generating land uses are located adjacent to the foreshore of Woolooware Bay and within the north eastern end of the catchment study area. The businesses in these areas include the Sharks Leagues Club, Woolooware Bay town centre commercial hub, Toyota, and a range of small to medium sized industrial operations. There are also several schools and child care centres scattered across the study area.

3.4 Natural Environment

The flood risk within the catchment is partly related to riverine, bay flooding from Woolooware Bay and mainly overland flow flooding. Woolooware Bay, and mainly the foreshore areas, both golf courses in the study area are identified as Environmentally Sensitive lands on the LEP Riparian Land and Watercourses and Terrestrial Biodiversity maps. Additionally, smaller areas including Woolooware Public School and Hagger Park adjacent to the northern side of Woolooware train station are also mapped as Environmentally Sensitive lands on the LEP Terrestrial Biodiversity map (see **Figures 3** and **4**).

Figure 3: LEP Terrestrial Biodiversity Map

Figure 4: Riparian Land and Watercourses Map

More detailed mapping of native vegetation communities is provided on Council Shire Maps., as depicted by **Figure 5**.

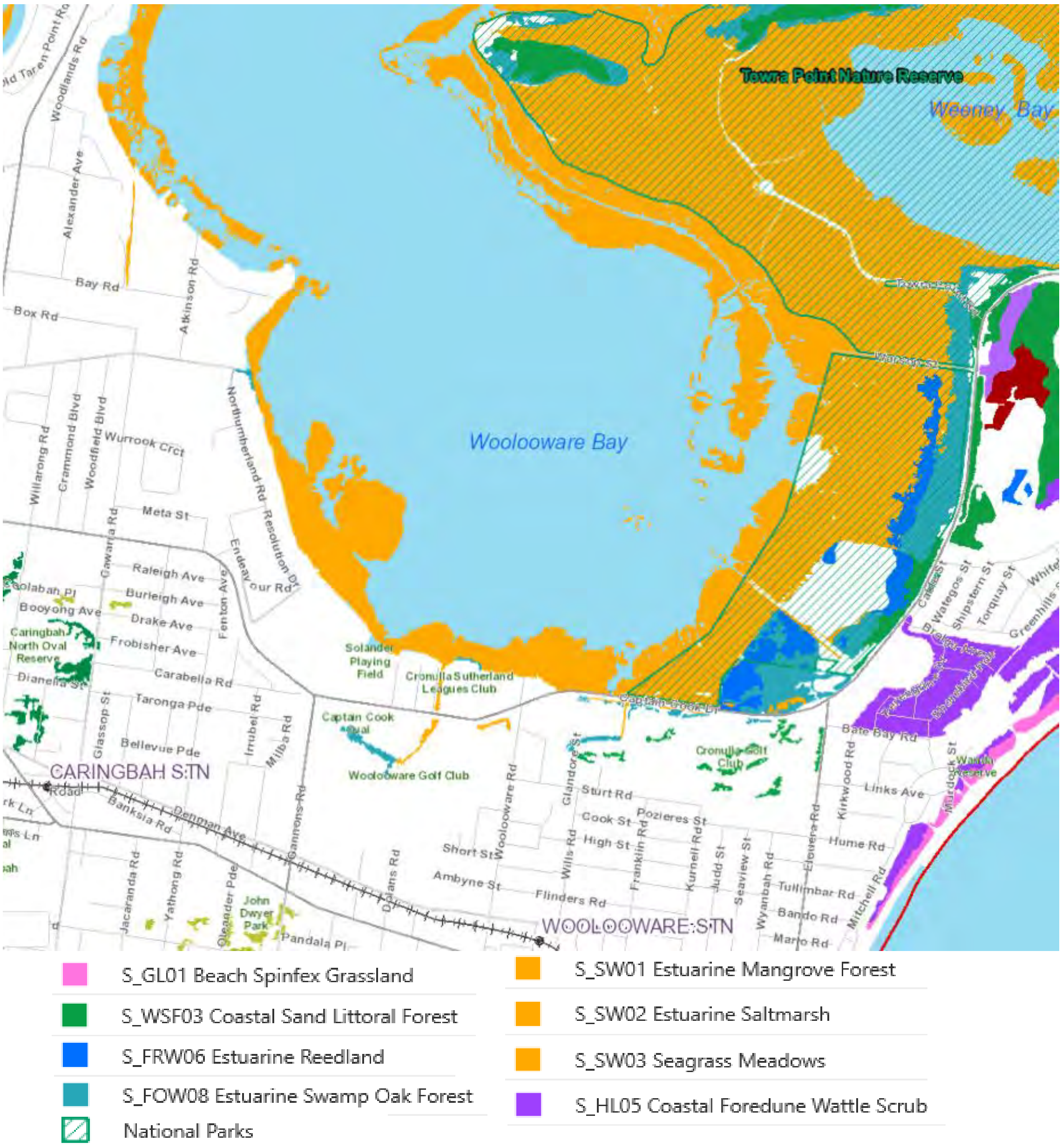

Figure 5: Vegetation Communities (Source: Council Shire Maps)

The northern edge of the study area, generally known as the Towra Point Nature Reserve, is mapped as National Park.

3.5 Flood Behaviour

Woolooware Bay catchment is typical of many urban catchments in Sydney where the mode of inundation is overland flooding rather than mainstream flooding. With mainstream flooding floodwaters exit from an open channel or river and inundate the surrounding floodplain. With overland flooding there are no, or very few open channels and overland flooding occurs when the capacity of the Council pit and pipe drainage network is exceeded. Typically this occurs in events more frequent than the 20% AEP.

Overland flooding in the catchment occurs through private property and along roads but may not be perceived by land owners as significant, as it occurs infrequently and is of short duration and therefore may be missed. It is generally of shallow depth and low velocity and thus most residents might not perceive that flooding is a hazard or should limit their development potential.

The main development in the catchment is detached houses with increasing numbers of dual occupancies and small town house and apartment developments. Commercial developments are located in areas largely free from flooding and in the lower catchment large parts comprise open space within the two golf courses. In the residential areas there are minimal areas of frequent and significant inundation but as redevelopment occurs there is an opportunity for Council to apply best practice in floodplain management.

The key issues associated with how development might affect flood behaviour would primarily relate to ensure as all new works accord with Council's flood controls (mainly in regard to elevating house and garage floor levels) they also ensure that the proposed development (typically larger houses and more substantial fencing) will not divert floodwaters onto surrounding properties with adverse consequences on others. The impacts of climate change induced sea level rise and rainfall increase must also be considered.

4 General Planning Framework

4.1 Overview

The section outlines the existing planning framework that can be relevant to the implementation of FRM planning strategies. The planning framework consists of an array of legislation, government directives, policies and guidelines, statutory and non-statutory plans, and Council policies and practices. This provides a basis for understanding the planning recommendations discussed in later sections of this report.

The formulation and implementation of FRMS&Ps is the cornerstone of the NSW Government's Flood Prone Land Policy. As with other local planning processes, the preparation of FRMPS&s is a Council responsibility. The planning recommendations ultimately incorporated within a FRMS&P and adopted by Council will subsequently require implementation through the separate planning processes, principally governed by the *Environmental Planning and Assessment Act 1979* (**EP&A Act**).

The imposition of planning controls can be an effective means of managing flood risks associated with future development (including redevelopment). Such controls might vary from prohibiting certain land uses in areas of high flood risk to specifying development controls.

In principle, the degree of restriction that is imposed on development due to flooding should relate to the level of risk that the community is prepared to accept after balancing economic, environmental and social considerations (i.e. the application of the merits based approach required by the FDM). In practice, the planning controls that may ultimately be imposed are influenced by a complex array of considerations including state imposed planning policy and directions, existing local planning strategies and policies and ultimately the acceptability of conditions that could be imposed through the development application process.

The following provides an outline of current policy that is potentially relevant because it either directs the FRM planning controls that could be adopted or affects the way flood risk is identified in the planning controls.

4.2 The FRMS&P Relationship with EP&A Legislation

In 1984 the NSW State Flood Policy was introduced disbanding the mandatory application of a singular 100 year flood standard and required local Councils to prepare individual floodplain management plans based on a 'merit based approach'. The first Floodplain Development Manual (**FDM**) was published in 1986 to assist Councils in this task.

While the policy has evolved over time it has remained fundamentally the same, with a new Manual being published but not gazetted in 2001 and the current policy and Manual published and gazetted in 2005. The current FDM is under review but this process is unlikely to be completed within the timeframe of this study.

The Manual and Policy have changed over time but have principally retained the following key principles:

a. Local Government is responsible for FRM in NSW with financial and technical support being provided by the State Government. The actions, decisions and information provided by Council and exercised in this duty are indemnified through the provisions of Section 733 of the *Local Government Act, 1993*. Indemnity is provided where Council acts in good faith, which is deemed to be in accordance with the principles of the FDM unless proven otherwise.

b. A merit approach is to be adopted for the purposes of formulating a FRMS&P that provides a basis for decision making in the floodplain. This is in recognition that flood prone land is a valuable resource which should not be unnecessarily sterilised by the rigid application of prescriptive criteria, and to avoid the approval of inappropriate proposals. The merit approach is defined in the FDM as follows:

   The merit approach weighs socio-economic, ecological and cultural impacts of land use options for different flood prone land areas together with flood damage, hazard and behaviour implications, and environmental protection and wellbeing of the State's rivers and floodplains.[4]

The level of flood risk acceptable to the community is to be determined through a process typically overseen by a committee comprised of local elected representatives, community members and State and Local Government officials (including the SES). This process is shown in **Figure 6**.

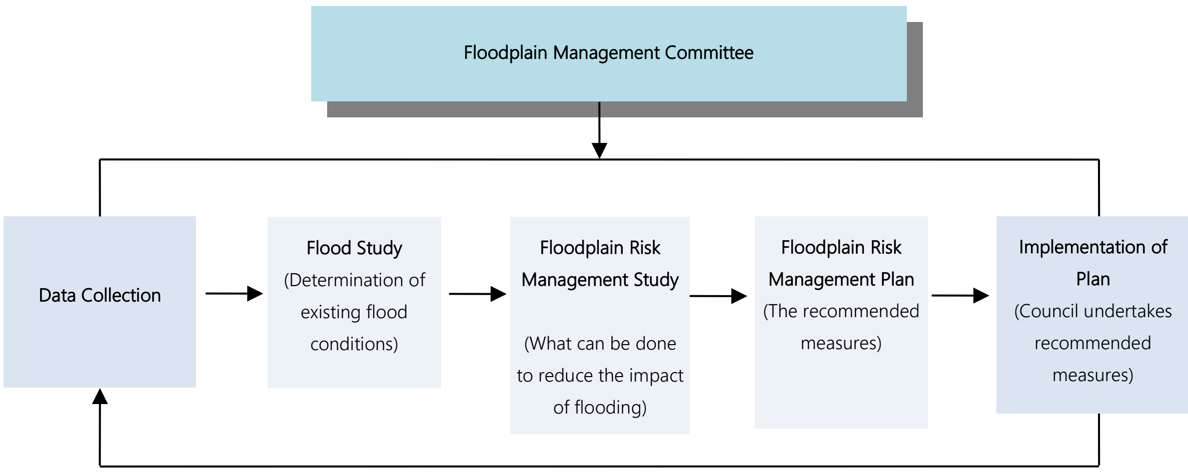

Figure 6: NSW FRM Process (Adapted from FDM 2005, pg. 6)

The ultimate intent is to prepare FRMS&Ps for individual floodplains that are adopted by Councils. FRMS&Ps should investigate and adopt an integrated mix of management measures that address existing, future and continuing risk.

The FDM and planning controls under the EP&A Act should not be considered as providing alternate approaches. The Flood Prone Lands Policy and Manual are separate to the principal planning legislation in NSW, being that contained within the EP&A Act and associated Regulations. Ultimately,

[4] 2005 Manual, NSW Government, 2005, page 23.

the planning recommendations of a FRMS&P may be reflected in planning instruments and policies brought into force in accordance with the EP&A Act.

While the EP&A Act and Regulation indirectly refers to flooding as an issue requiring consideration in some circumstances[5] this legislation does not refer to the Flood Prone Lands Policy or the FDM. The plans prepared under the EP&A Act provide the relevant considerations for the assessment of proposals involving development or an activity that could affect the environment (ie via a DA, complying and exempt development or an activity such as major road infrastructure under Part 5 of the EP&A Act).

The FRMS&P can provide appropriate input to the EP&A Act planning processes in 3 ways:

- providing direction at a local and state strategic planning level in addressing FRM (e.g. where new or higher density urban areas should be located and the distribution of land uses therein)
- recommendation of development controls to be incorporated in appropriate planning instruments (e.g. LEPs and DCPs) to mitigate the risk to development where permitted in the floodplain
- ensuring that the planning controls and associated documents such as. S10.7 (previously S149) Planning Certificates contribute to ensuring the community is appropriately informed about any flood risk.

To understand how these outcomes may be best achieved, it is important to consider the existing EP&A Act framework and guidelines that relate to FRM.

4.3 Flood Planning Guidelines

On January 31, 2007 the NSW Planning Minister announced a new guideline for development control on floodplains (**2007 Guideline**). An overview of the new Guideline and associated changes to the EP&A Act and Regulation was issued by the Department of Planning in a Circular dated January 31, 2007 (Reference PS 07-003). The 2007 Flood Planning Guideline issued by the Minister in effect related to a package of directions and changes to the EP&A Act, Regulation and FDM.

This 2007 Guideline provided an amendment to the FDM. The Guideline confirmed that unless there are "exceptional circumstances", Councils were to adopt the 100 year flood as the flood planning level (FPL) for residential development, with the exception of some sensitive forms of residential development such as seniors living housing. That Guideline provided that controls on residential development above the 100 year flood could only be imposed subject to an "exceptional circumstances" justification being agreed to by the Department of Planning (now DPIE) and the Department of Natural Resources (previously the Office of Environment and Heritage and now part of DPIE[6]) prior to the exhibition of a Draft LEP or Draft DCP.

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[5] For example, in the determination of what is designated development for the purposes of the Act and therefore requiring the preparation of an Environmental Impact Statement.

[6] The Environment, Energy and Science Group in DPIE

The direction regarding the selection of an FPL in the 2007 Guideline did not apply to all land uses (only standard residential) and recognised the need to consider the full range of flood sizes, up to and including the probable maximum flood (PMF) and the corresponding risks associated with each flood. Where there was a reason ('exceptional circumstances') a different FPL not based on the 100 year flood (plus freeboard) could also be applied with government approval. The direction did not apply to pre-existing planning controls.

Prior to finalising our report, the NSW Government introduced significant changes to the FRM statutory planning framework across NSW with the Implementation of the DPIE Flood Prone Lands Package. These changes were initiated on 14 May 2021 and came into effect on 14 July 2021.

The Flood Prone Land Package changes were introduced in a DPIE Planning Systems Circular issued to Councils in final form on 14 July 2021.

The principal changes relate to the harmonisation of the FRM provisions of all LEPs but with important incidental implications for DCPs and flood planning maps. Notably, the prescription in the 2007 Guideline regarding the adoption of the 100 year flood as the FPL for residential development was abandoned. The current Guideline now allows Council greater autonomy in determining FPLs.

The 2021 Circular provided advice to Councils on the recent changes that included:

- an amendment to clause 7A of Schedule 4 to the *Environmental Planning and Assessment Regulation 2000* (**the Regulations**)
- a revised local planning direction regarding flooding, issued under section 9.1 of the EP&A Act
- two LEP clauses which introduce flood related development controls (one mandatory and one optional)
- all flood planning overlay maps are now deleted from LEPs
- introduction of a new guideline, "Considering flooding in land use planning Guideline" dated 14 July 2021 (**the 2021 Guideline**)
- revoking the 2007 Guideline.

The 2007 Guideline influenced Council's existing FRM controls, while the 2021 Guideline standardised FRM LEP provisions and encouraged Councils to undertake changes to its DCP and flood planning maps. Notable direction provided by the 2021 Guideline includes:

- Councils should define their FPA[7]s and FPLs in their development control plans (DCPs) and outline if there are multiple FPAs/FPLs and where they apply.
- It is suggested that Councils could attach their adopted flood policies, flood studies and FRMS&Ps to their DCPs to ensure they are considered in the assessment of a DA. However, in our view this is unnecessary. Ideally all relevant recommendations of a FRMP should be

[7] This is a reference to the Flood Planning Area which is defined as the area of land at or below the flood planning level (FPL).

translated to a DCP and if necessary Council adopted FRMPS&Ps could simply be referred to.

- Guidance on seeking the application of the optional "Special Flood Considerations" (**SFC**) LEP clause and possible complementary DCP changes.

- Noting that flood planning maps should be made publicly available (in ways other than within an LEP) which could entail being published in DCPs, other relevant environmental planning instruments or on a council website.

The following sections of this report take into consideration the changes introduced with the 2021 Flood Prone Lands Package, including the new Guideline.

4.4 Section 9.1 Directions (Formerly Section 117)

Ministerial directions pursuant to Section 9.1(2) of the EP&A Act specify matters which local councils must take into consideration in the preparation of LEPs. Direction 4.3, deals specifically with flood [liable] prone land and was amended as part of the 2021 Flood Prone Land Package. The Direction applies to all councils that contain flood prone land when an LEP proposes to "create, remove or alter a zone or provision that affects flood prone land."

The primary differences between the current and preceding Directions relate to a removal of the reference to the 2007 Guideline and the restriction on introducing an FPL that was inconsistent with that Guideline. The new Direction 4.3 requires that a Planning Proposal should introduce provisions that give effect to, and are consistent with, the 2021 Guideline.

Both the preceding and current Directions require draft LEPs to ensure:

- consistency with the principles of the FDM (including the Guideline)

- do not rezone flood prone land zoned special use areas, recreation, rural or environmental protection to a residential, business, industrial or special use area zone

- do not permit development in floodways that would result in significant flood impacts on others, permit a significant increase in development on the floodplain, require substantial government spending on flood mitigation, or allow development without consent except for agriculture or flood mitigation works

Clause (6) of the Direction specifies that a variation to the Direction may be permitted where it is minor or accords with an FRMS&P.

4.5 EP&A Amendment (Flood Related Development Controls Information) Regulation 2007

Schedule 4, clause 7A of the Regulations specifies information that can be included on s10.7 Planning Certificates. Schedule 4 was amended in 2007 and again in 2021 in regard to notification of flood related development controls[8].

Councils continue to be required to distinguish between land where different categories of flood-related development controls apply. In particular:

- Clause 7A(1) requires inclusion of a notation on planning certificates if the land or part of the land to which the certificate relates is within the FPA and subject to flood related development controls.
- Clause 7A(2) require councils to include a notation if the land or part of the land to which the certificate relates is between the FPA and the PMF and is subject to flood related development controls.

The Guideline notes that if information is lacking, then an 'unknown' response should be provided until the information is made available and councils relevant flood-related development controls are updated. However, unmapped locations may also be subject to flood related development controls and these areas should be noted in the planning certificate.

In accordance with section 10.7(5) of the Act, Councils should include any additional information on flooding and flood risk in this more expansive planning certificate.

4.6 Climate Change Considerations

The FDM highlights the need for climate change to be considered in an FRMS&P to understand both the potential effects on flood behaviour and as a factor when evaluating management strategies.

The (then) NSW Department of Environment & Climate Change issued an FRM Guideline entitled "Practical Consideration of Climate Change" (25.10.2007). The Guideline addresses the consequences of potential changes in sea levels and rainfall intensities associated with climate change predictions. Due to some level of uncertainty with the timing and magnitude of climate change effects, this Guideline recommends undertaking sensitivity analysis to understand the potential implications of climate change when modelling flood behaviour and frequency, and to test the robustness of management strategies.

As part of the management strategies for future development, the Guideline recommends that where climate change ramifications are considered minor that either existing FPLs be adopted and the potential for risk to increase over time be documented and the community informed, or higher FPLs that include a climate change factor be used.

Where climate change factors are considered significant, the Guideline recommends a range of strategies for future development including:

- developing in alternate locations and preparing for planned retreat

[8] Flood-related development controls are not defined but would include any development controls relating to flooding that apply to land, that are a matter for consideration under section 4.15 of the Act.

- applying a combination of higher fill and floor levels to maximise the height of habitable floors where this would have minimal environmental impacts

- promoting uses in vulnerable areas that are more compatible with the long term risk (e.g. recreation areas, agriculture or environmental purposes)

- consider types of development that have a limited life span or are more capable of relocation (e.g. tourist or short term caravan parks, and tourist or commercial development where investment decisions are based upon known conditions and a committed program of abandonment and removal)

- designing developments with more vulnerable components in less exposed parts of the site

- building-in the potential for retrofit solutions in the future

- the staged construction of levee banks.

The Policy notes that each management strategy has residual issues or produces consequential issues that also need to be resolved. These include:

- While floor levels may be raised, surrounding roads and services can continue to be periodically affected by flooding and/or tidal inundation which restricts access and damages public infrastructure. In the case of tidal inundation, this can ultimately make areas unliveable as the period of inundation lengthens with gradual sea level rise.

- The filling of individual properties as redevelopment occurs can cause interim drainage issues for isolated unfilled properties. A comparable scheme was established decades ago as an approach to address legacy flood risks in Kurnell (WMA 2009, pg.16) but was ultimately abandoned because of such problems.

- Stormwater could be trapped behind levees and this would require management with flood gates and pumping during flood events.

- While levees could protect areas from tidal inundation by surface water, ground water flooding may need to also be managed. This issue was identified for low lying inner suburbs of Newcastle and a management strategy was adopted by Newcastle City Council in 2016 that involved installing equipment to monitor sea and groundwater levels and installation of ground water drains and pumps when needed.

- Visual and amenity impacts can arise associated with the sporadic filling and/or raising of individual properties and the construction of levee banks near the coastline. The filling and/or raising of individual properties can have implications for the streetscape and character of a locality and can lead to overshadowing and privacy impacts between neighbours. The consequent need to increase the height of buildings needs to be tested against relevant planning controls such as building heights to determine whether adjustments to the controls would be warranted and acceptable.

The above measures need to be assessed against a number of evaluation criteria set out in the Climate Change Guideline, such as impacts on existing and future flood behaviour, cost/benefit, additional emergency management requirements, aesthetic and environmental issues, and the potential to adapt with changed climate change information.

The stated purpose of Councils Sea Level Rise Policy (July 2020) is "…to outline the principles guiding Council's approach to sea level rise within the Sutherland Shire." Clause 2 of the Policy states it applies as follows:

> *The policy applies to land that is predicted to be inundated up to 2.22 m AHD in the 1% annual exceedance probability (AEP) 'storm tide' event of 1.5 m AHD plus a sea level rise of 0.72 m projected to occur in 2100 under the adopted emissions scenario.*

Revised flood modelling undertaken as part of the FRMS&P will incorporate sea level rise predictions.

The Policy specifies the projected sea level rise levels derived from the Intergovernmental Panel on Climate Change (**IPCC**) fifth assessment report (AR5) 10 year increments up to 2100, and clause 3.3 provides:

> *Council will consider sea level rise when determining development applications and when preparing planning proposals, policies, flood studies, floodplain risk management studies and plans, and coastal management programs.*

A key issue for council is that while the LEP and Council's Sea Level rise Policy requires consideration of climate change effects, no specific guidance is provided by the DCP. The evaluation of planning management options later in this report will discuss what FPLs and other planning controls should be applied to different land uses depending on factors such as vulnerability to flood hazard and the design life of the development relative to timing for sea level rise.

4.7 Regional Planning Strategies

4.7.1 A Metropolis of Three Cities – South District Plan

The Greater Sydney Commission (**GSC**) published the 'South District Plan' in 2018 in association with the regional plan, 'A Metropolis of Three Cities'. The South District is projected to grow by 83,500 dwellings between 2016 and 2036, which represents 12% of the total dwelling growth in the Sydney Metropolitan area. The relevant priorities set for the LGA are in the sustainability chapter relating to a resilient city. These include:

Planning Priority S18 – Adapting to the impacts of urban and natural hazards and climate change. The objectives under this planning priority are:

- *Objective 36 – People and places adapt to climate change and future shocks and stresses*
- *Objective 37 – Exposure to natural and urban hazards is reduced*

The District Plan notes[9] that the state government has adopted the FDM which "…provides councils with policy directions and tools for managing exposure to flooding."

[9] South District Plan, pg.110.

4.8 Local Planning Strategies

Council produced a Housing Strategy in 2014. This strategy looked at increasing housing choice in general and specifically housing for seniors and smaller households. The recommendations of this Strategy, to the extent relevant to the study area has now been implemented with changes to the *Sutherland Shire Local Environmental Plan 2015* (**SSLEP**).

The 2017 – 2027 Sutherland Shire Community Strategic Plan (**CSP**) adopts Strategic Actions 2.4.2 and 2.4.3 which, respectively, are to monitor and manage the environment to minimise the impacts of natural disasters, and to build community resilience to respond and adapt to environment and climate risks.

As required by s3.9 of the EP&A Act, Council prepared a Local Strategic Planning Statement (**LSPS**) that was adopted on 15 September 2020, and will be reviewed every 7 years. The LSPS provides a 20-year vision for planning in the LGA and the direction to achieve that. It provides a direct line of sight to the South District Plan and Council's CSP and shows how targets such as housing and employment opportunities will be met within a local context.

There are no substantial proposed changes to development potential available under current planning instruments discussed below. The LSPS notes (pg. 30) that based on past trends population growth in the LGA there could be approximately 30,000 more people and a consequent demand for 15,000 new dwellings between 2016 and 2036 (pg. 40).

Key observations for the Woolooware Bay catchment are that major landuse will remain residential, and consequently a mix of low and high density residential located within areas affected by flooding. There has been no significant change in zoning in recent years and high density residential zones are concentrated along the railway corridor and in the eastern sub-catchment in North Cronulla. The Caringbah town centre is the only suburban centre discussed in the strategy that is located in the catchment, albeit it is at the top of the catchment and has generally low to no flood risk.

In regard to potential growth related to employment generating development, the LSPS (pg.68) specifically discusses the following sites within the study area:

- the 4ha of IN4 zoned working waterfront land as regionally important to the maritime industry
- that the 12ha B7 zone land soon to be vacated by Toyota will be a strategically important employment site.

The long term development potential of these sites, and other employment lands, need to be managed having regard to flood risks directly to the sites, and associated infrastructure and restricted access during floods, particularly as sea level rise impacts increase.

The LSPS Planning Priority 21 is to "manage risks to from hazards" (pgs. 94-97). This includes to "Continue to manage the risk to life and property from natural hazards through the planning framework" (Action 23.1).

4.9 State Environmental Planning Policies (SEPPs)

A State Environmental Planning Policy (**SEPP**) is a planning document prepared in accordance with the EP&A Act by the DPIE and eventually approved by the Minister, which deals with matters of significance for environmental planning for the State.

Regional Environmental Plans (**REP**s) were previously a type of environmental planning instrument prepared under the Act (since repealed) and existing REPs are now deemed SEPPs.

No SEPP has been prepared dealing specifically with the issue of flooding, but some regulate development in response to potential flood risks.

Those SEPPs of potential relevance to the study area are discussed below.

4.9.1 SEPP (Infrastructure) 2007

State Environmental Planning Policy (Infrastructure) 2007 aims to facilitate the effective delivery of infrastructure across the State by identifying development permissible without consent.

Clause 15 governs public authorities' consultation with councils for development with impacts on flood liable land (as defined by the PMF).

Part 3 Division 7 specifies that development for the purpose of flood mitigation work may be carried out by a public authority without consent. Part 3 Division 20 specifies that development for the purpose of stormwater management systems may be carried out by a public authority without consent.

4.9.2 Seniors Living SEPP

SEPP (Housing for Seniors or People with a Disability) 2004 (**Seniors Living SEPP**) applies to urban land or land adjoining urban land where dwellings, hospitals, existing clubs and similar uses are permissible. This SEPP is under review but the outcome of that process is not final.

The current Seniors Living SEPP would apply to parts of the study area and would effectively override Council's planning controls to permit residential development for older persons and persons with a disability, to a scale permitted by the SEPP. Notwithstanding, Clause 6(2)(a) of the SEPP restricts its application if land is identified as a "floodway" or "high flooding hazard" in Council's LEP.

SSLEP does not identify floodways or areas of high flooding hazard. Further, the standard instrument FRM clauses and are not structured to accommodate the inclusion of these specific flood hazard types within the ambit of the clauses or on LEP maps.

While the LEP provision cannot be structured to exclude the application of the Seniors Living SEPP on FRM grounds, Council could review its LEP and DCP provisions to provide complementary FRM considerations, provided that they are not inconsistent with the SEPP. The new LEP flood clause and the 2021 Guideline does now allow Council the flexibility to identify alternate FPLs/FPAs for different land uses. Additionally, as discussed later in this report, the DCP provisions can provide further controls that are tailored to reflect the vulnerability of uses such as seniors living housing.

4.9.3 Codes SEPP

The specification of exempt and complying development is primarily governed by *State Environmental Planning Policy (Exempt and Complying Development Codes) 2008* (the **Codes SEPP**). The Codes SEPP effectively provides approval pathways as alternatives to a full DA for certain low impact development. Exempt development requires no approval provided it complies with certain criteria. Complying development must meet certain criteria but also requires an approval in the form of a complying development certificate (**CDC**) which must be issued by Council or a private certifier subject to specified conditions.

The Codes SEPP is divided into a number of "Codes" that deal with exempt development and different types of complying development. Those Codes of specific relevance to the study area or LGA are the Exempt Development Codes (Part 2), the General Housing Code (Part 3), the Rural Housing Code (Part 3a) and the Commercial and Industrial (New Buildings and Additions) Code (Part 5A.

The relevant clauses of the Codes SEPP apply to "flood control lots" defined as:

> ***flood control lot*** *means a lot to which flood related development controls apply in respect of development for the purposes of industrial buildings, commercial premises, dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (other than development for the purposes of group homes or seniors housing).*
>
> ***Note****. This information is a prescribed matter for the purpose of a certificate under section 149 (2)* [now 10.7] *of the Act.*

Flood control lots are required to be noted as such on a S10.7 Certificate.

Some exempt development is not permitted on a Flood Control Lot (e.g. earthworks, retaining walls and structural support is not exempt development on a flood control lot per clause 2.29 of the SEPP).

The General Housing, Rural Housing and Commercial and Industrial (New Buildings and Additions) Codes also provide several exclusions as to what can be complying development on a flood control lot. Most complying development is permitted on Flood Control Lots where a Council or professional engineer can certify that the part of the lot proposed for development is not a:

- flood storage area
- floodway area
- flow path
- high hazard area
- high risk area (see for eg Clause 3.36C).

The above terms are defined directly by the Codes SEPP or indirectly by the FDM which is referred to by the Codes SEPP for that purpose. These definitions are:

flood storage areas [means] *those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage* *areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.* [FDM].

floodway areas [means] *those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.* [FDM].

flow path *means a flow path identified in the council's flood study or floodplain risk management study carried out in accordance with the Floodplain Development Manual.* [Codes SEPP].

high hazard area *means a high hazard area identified in the council's flood study or floodplain risk management study carried out in accordance with the Floodplain Development Manual.* [Codes SEPP].

high risk area *means a high risk area identified in the council's flood study or floodplain risk management study carried out in accordance with the Floodplain Development Manual.* [Codes SEPP].

The Codes SEPP specifies various controls in relation to floor levels, flood compatible materials, structural stability, flood affectation, safe evacuation, car parking and driveways (see Clause 3.36C). These controls must be imposed on a CDC where the development is located on a flood control lot. The minimum floor level must be adopted by Council as part of a DCP in order for it to be imposed on a CDC[10]. Despite this, it is expected that a Certifier would seek to impose a minimum floor level that Council would normally apply, and consequently it is desirable that such information be broadly and clearly publicised.

Important considerations for the FRMS&P, regarding establishing rules for development that could be approved as complying development, is the defining of any of the 5 floodplain "high risk/hazard" areas (where complying development is excluded) and setting of minimum floor levels. Flow paths, high hazard areas and high risk areas are required to be identified in a Council prepared Flood Study or FRMS&P to be relevant exclusion criteria under the Codes SEPP.

The objective of how the FRM&P deals with complying development should be to ensure that such development does not lead to increased flood risk to property and persons as a consequence of the application of the CDC process, in comparison to outcomes otherwise likely to be achieved through the full DA process. At the same time, the outcome of the FRMS&P should not create unnecessary administrative burdens on the public and Council by requiring a DA where this would be of no likely benefit to reducing flood risk.

Council could proactively provide advice to the public as to where the Codes SEPP applies. The flood maps produced for planning purposes could achieve this by for example aligning areas identified as higher risk areas with those areas within which complying development is excluded under the Codes SEPP.

[10] See for example clause 3.5(2)(a) of the Codes SEPP that specifies "(a) if there is a minimum floor level adopted in a development control plan by the relevant council for the lot, the development must not cause any habitable room in the dwelling house to have a floor level lower than that floor level,"

Councils' brief identified that a lack of guidance causes the following issues with the application of the Codes SEPP:

- making a confident assessment of the status of a flood control lot and where a CDC could be issued

- enabling a proper assessment of the controls listed in Section 3A.38 of the Codes SEPP.

A 'Flood Control Lot' is a lot where 'flood-related development controls apply' for the purposes specified development. 'Flood-related development controls' is not defined but would include any development controls relating to flooding that apply to land, that are a matter for consideration under section 4.15 of the Act[11]. These development controls may apply through an LEP or Development Control Plan (**DCP**).

The difficulty in identifying flood control lots could however relate to uncertainty in regard to where the relevant flood-related development controls geographically apply for the following reasons;

- The SSLEP flood clause applies to land mapped on the LEP Flood Planning map <u>and</u> other land below the 1:100 ARI plus 0.5m Freeboard.

- The DCP flood-related controls (Chapter 40) generally applies to land for which there is flood mapping (up to the PMF) but with various qualifications. However, clause 5.1(1) provides that if a development is confined to the flood free part of a site then "…no flood related development controls will be imposed other than those relating to site evacuation." Additionally clause 5.2(6) provides that where residential development is sited above the 1% AEP plus 0.5m freeboard FPL "…the proposal will be considered to satisfy flood risk management objectives and no flood related development controls will be imposed."

- The DCP also applies to land identified as "Initial Assessment Potential Flood Risk" where Council might specify a 1% AEP flood level (equivalent to a 1:100 ARI) for the purposes of applying the DCP controls, or will request a flood study. No freeboard is mentioned but Council advises that the area is generously mapped such that it is likely to include the land potentially flood affected up to a PMF. Note at present there are no areas mapped as "Initial Assessment Potential Flood Risk" in the study area (as confirmed on Council's GIS mapping) however the DCP maps are yet to be updated to show such areas.

- Land that is not yet subject to flood mapping could be subject to flood-related development controls. The LEP and DCP controls could appropriately apply to land if found to be subject to flooding based on a site assessment even if not mapped[12]. Conversely, land mapped as "Initial Assessment Potential Flood Risk" might later be determined by a flood study to not warrant the application of controls under the DCP.

Without being able to map all the areas to which flood-related development controls apply it would be difficult to simply identify flood control lots through a straightforward GIS exercise. However, in

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[11] See 2021 Guideline. Page 2.

[12] For example, a flood study requested by Council during a DA assessment process could confirm that a site is flood affected. This is consistent with the 2021 Guideline (pg.7)

principle this does not appear to be a major issue for the Sutherland LGA. The DCP flood maps alone show flood risk precincts and "Initial Assessment Potential Flood Risk" areas that are inclusive of all areas that could be potentially flooded up to the PMF, while differentiating areas below the 1:100 ARI flood plus 0.5m freeboard, which should be sufficient to identify all flood control lots. A potential problem is the currency of some flood mapping, with a tendency for the LEP and DCP maps to be out of date for long periods due to the complexity and time required to have them formally amended.

Actions that could be pursued by Council to provide greater certainty and ensure appropriate FRM development outcomes. Codes SEPP approval pathways will be discussed in the management strategies explored later in this report, but will basically focus on simplifying the system and providing greater certainty. This includes consolidating all flood mapping so that they can be more easily kept up to date.

4.10 Local Environmental Plans

The EP&A Act was amended to facilitate the reproduction of planning instruments into a standardised format known as a 'standard instrument' and commonly referred to as the 'LEP template'. Section 3.20 of the EP& A Act deals with the prescribing of a standard instrument for LEPs.

The standard instrument originally contained no compulsory clauses or map requirements specifically relevant to addressing flood hazards. At the time of preparing Councils LEP, the DPIE had adopted a model local clause in regard to flooding which Council had adapted and applied together with flood LEP overlay mapping. The recent Flood Prone Land Package changes have introduced a changes to FRM provisions.

4.10.1 Sutherland Shire Local Environmental Plan 2015

Overview

The Woolooware Bay Catchment is governed by the *Sutherland Sire Local Environmental Plan 2015* (**SSLEP**). The SSLEP had originally adopted clause 6.3 which was similar to the model LEP flood planning clause and defined the FPL as the 100 year flood plus 0.5m freeboard. The SSLEP now applies the compulsory Flood Planning Clause 5.21 which allows Council to define the FPL/FPA in the DCP. The LEP originally contained flood overlay maps which were automatically deleted with the introduction of clause 5.21[13].

Council advises that they opted into inclusion of the Special Flood Considerations Clause which is yet to inserted into the LEP.

Additionally, clauses 6.7 and 6.10 of the SSLEP calls up mapping of 'Environmentally Sensitive Land' being riparian land, watercourses, and the foreshores of Port Hacking, Georges River, Woronora River and Botany Bay. Land affected by these clauses are subject to development restrictions primarily because of biodiversity, environmental and scenic quality. Areas identified by these maps also serve an inter-related purpose that incidentally achieve an FRM outcome.

[13] While the LEP no longer refers to flood planning maps the DPIE is deferring the removal of the maps from the legislation website to allow Councils in NSW time to organise alternate display arrangements.

Appendix B provides a review of relevant LEP provisions in order to consider whether they might be rationalised to improve FRM outcomes.

4.10.2 Review of Compatibility of Land Use Zones with Mapped flood Risk

The land use zonings applying to the study area are depicted on **Figure 7**. An overlay of the flood hazard mapping and related, produced by WMA as part of the FRMS&P process, over existing zoning was interrogated using a GIS mapping facility to determine whether there were any areas inappropriately zoned.

The methodology for the preparation of these flood hazard and planning constraint maps, and the implications for development in each constraint category, are based on 'Guideline 7-5 of the Australian Disaster Relief Resilience Handbook' (AIDR, 2017). The Guideline recommends adoption of four flood planning constraint categories (**FPCC**s), as reproduced in **Table 3** below:

Table 3: Flood Planning Constraint Categories (FPCC) (AIDR, 2017)[14]

FPCC	Constraint Subcategory
1	a) Floodway or flood storage area in the Defined Flood Event (DFE)* b) Flood hazard H6 in the DFE
2	a) Floodway in events larger than the DFE b) Flood hazard H5 in the DFE c) Emergency response (isolated and submerged areas) d) Emergency response (isolated but elevated areas) e) Flood hazard H6 in floods large than the DFE
3	Remaining area below the DFE plus freeboard
4	Remaining area below the PMF or Extreme Flood

Note: * DFE is defined flood event more commonly referred to as the flood used to establish the FPL in NSW.

Consistent with best practice (as set out in the planning and FRM policies outlined above) it is important to consider the best available flood information when undertaking strategic planning. While the use of FPCCs needs to have regard to the context of different areas, generally most land uses would be considered incompatible with the flood risk in the FPCC 1 areas and in the FPCC 2 areas where mitigation works such as filling work could not be acceptably implemented with no material external impacts on others in the floodplain, and evacuation capabilities cannot be satisfactorily resolved.

[14] This table has been adapted from information extracted form Table 3 of Guideline 7-5. The reference to H1-H6, is a reference to hazard categories determined in accordance with the Australian Disaster Resilience Handbook Collection Guideline 7-3 Flood Hazard (2017)

In FPCC areas 1 and 2 it is preferable not to encourage flood sensitive land uses or critical infrastructure and to ensure suitable access for evacuation purposes is available. The high level review of the SSLEP zoning maps for the study area indicates the following:

- FPCC areas 1 and 2, and generally areas subject to H4, H5 and H6 Hazard, are mostly within public roads. This does not pose any direct hazard to private property but will have implications for public infrastructure located within these roads and emergency management. The short duration - minimal warning time nature of the flooding within the study area supports the case for accepting shelter in place as an alternative to evacuation for development on existing urban zoned land.

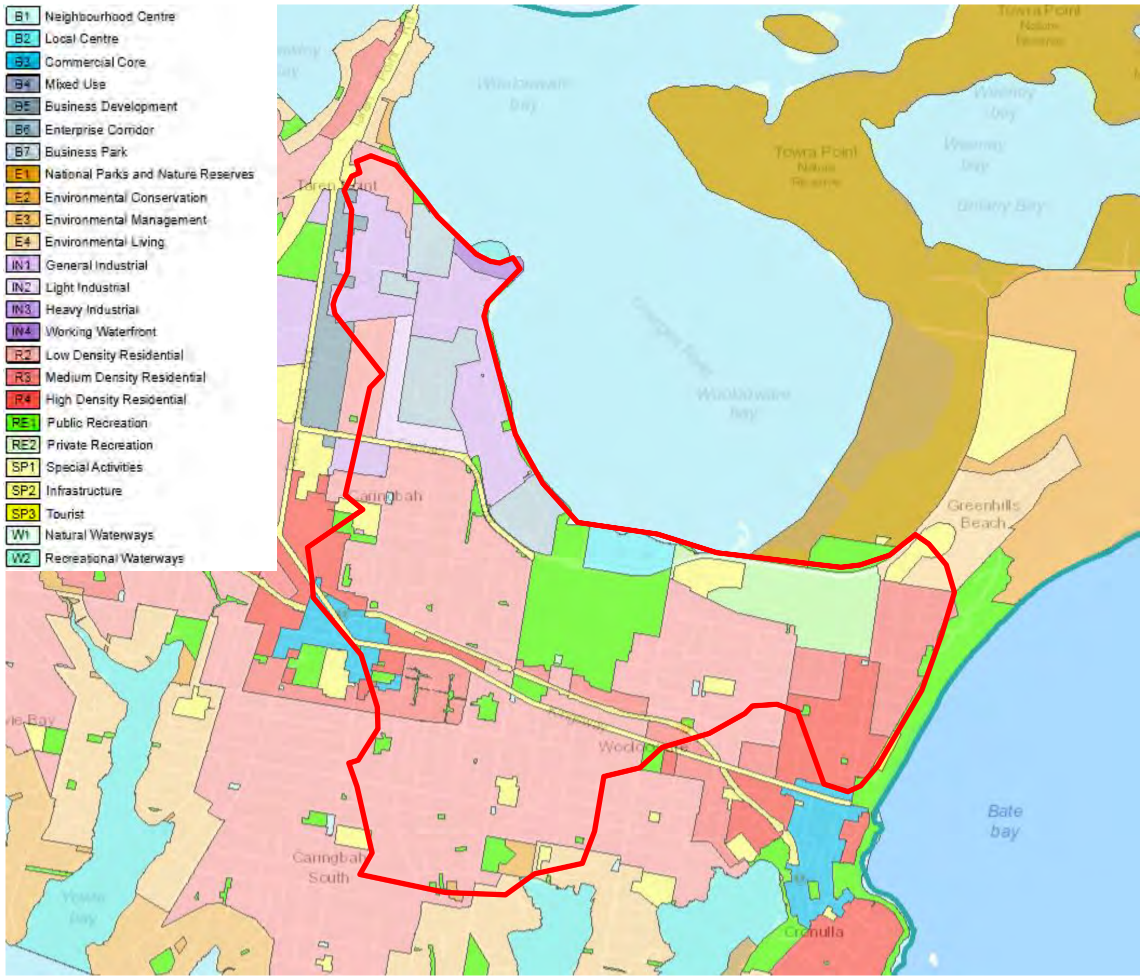
- Some areas subject to H4, H5 and H6 Hazard are located within the two golf courses within the study area which are zoned RE1 Public Recreation or RE1 Private Recreation. This is considered appropriate for FRM reasons. The SSLEP differentiates the zoning of the Woolooware Golf Club (RE2) from the Golf Course (RE1) however, there are no FRM reasons to review this, given the RE2 zoned site for the existing club is not affected by H5 or H6 Hazard.

- There are minor components of industrial lots zoned B7 Business Park on the northern and eastern side of Wurrook Circuit Caringbah subject to H4 and H5 Hazard but these areas appear to be isolated to an outdoor storage areas for pipes and front setbacks and outdoor car parking.

- Minor areas of the front properties zoned R3 Medium Density Residential in Denman Avenue are subject to H5 and H6 Hazard. Similarly, minor areas of the front setback of area of properties zoned R2 Low Density Residential in Carabella Road are subject to H5 Hazard.

- An overland flow path weaves in a northeast direction through residential properties zoned R2 southwest of the Jenola Hockey Fields and the intersection of the Kingsway and Gannons Road. These properties are developed for residential purposes. Options to manage the flood hazard in this area include voluntary installation of flood smart fencing (as discussed later) and to seek improvement in minimising obstructions to flood flows and improvements in the resilience of individual properties should redevelopment proposals be considered by Council in the future. While parts of these residential lots are affected by hazardous flooding, these types of options are considered more appropriate than reviewing existing zoning to decrease development opportunities.

Consequently, the above issues do not warrant review of zone boundaries. However, these flood hazards would be relevant considerations for any future development applications and rezoning proposals. Recommendations for consideration of such flood risks in both the strategic planning and development assessment processes are outlined later in this report.



Source: Base mapping - DPIE Planning Portal. Key – SSLEP 2015

Figure 7: Zoning overview within the Woolooware Bat catchment (red outline)

4.11 Sutherland Shire Development Control Plan 2015

The Sutherland Shire DCP was adopted by Council on 25 July 2017 and came into effect on 2 August 2017. The DCP applies to all land that the LEP applies to, except for land identified as a 'deferred matter' in the LEP. Both deferred matter areas are located outside of the Woolooware Bay Catchment.

Parts of chapters 38 and 40 of the DCP relate to stormwater and flood risk management respectively.

At the time of preparing this report, Council was in the process of considering any changes that may be required to the DCP as a consequence of the Flood Prone Land Package changes that commenced in July 2021. This report was prepared with regard to the DCP as existing prior to July 2021.

Part C of Chapter 40 of the DCP specifically addresses FRM for the area defined as flood prone land consistent with the FDM – that is all land potentially inundated by a PMF. This chapter of the DCP applies to all flood prone land but different development controls affect different types of development differently depending on the flood hazard associated with the location of the property within the floodplain. This is an application of the "flood planning matrix" approach first introduced to council as part of the Georges River FRMS&P.

Presently, the DCP relies on mapping, appended to the DCP, of the floodplain into low medium and high "flood risk precincts' (**FRP**s). Where existing flood mapping is incomplete, areas are mapped as being subject to "Initial Assessment Potential Flood Risk" using a rapid assessment methodology. This identifies the need for further investigations to determine what FRP applies to the land or whether it is flood free.

An example of the DCP flood maps for a part of the study area is provided as **Figure 8**. As depicted by this figure, most of the potentially flood affected parts of the study area is mapped as "Initial Assessment" pending completion and adoption of the Woolooware FRMS&P.

Source: Base mapping – Sutherland DCP 2015

Figure 8: DCP Flood Map (example)

For completeness, it is noted that the Council website provides on-line mapping derived from Council GIS system that depicts more complete and up to date flood mapping for the study area. This is shown on **Figure 9**.

A detailed critique of the relevant parts of these DCP chapters is provided in **Appendix C**. The following outlines the key issues that have been identified with the DCP:

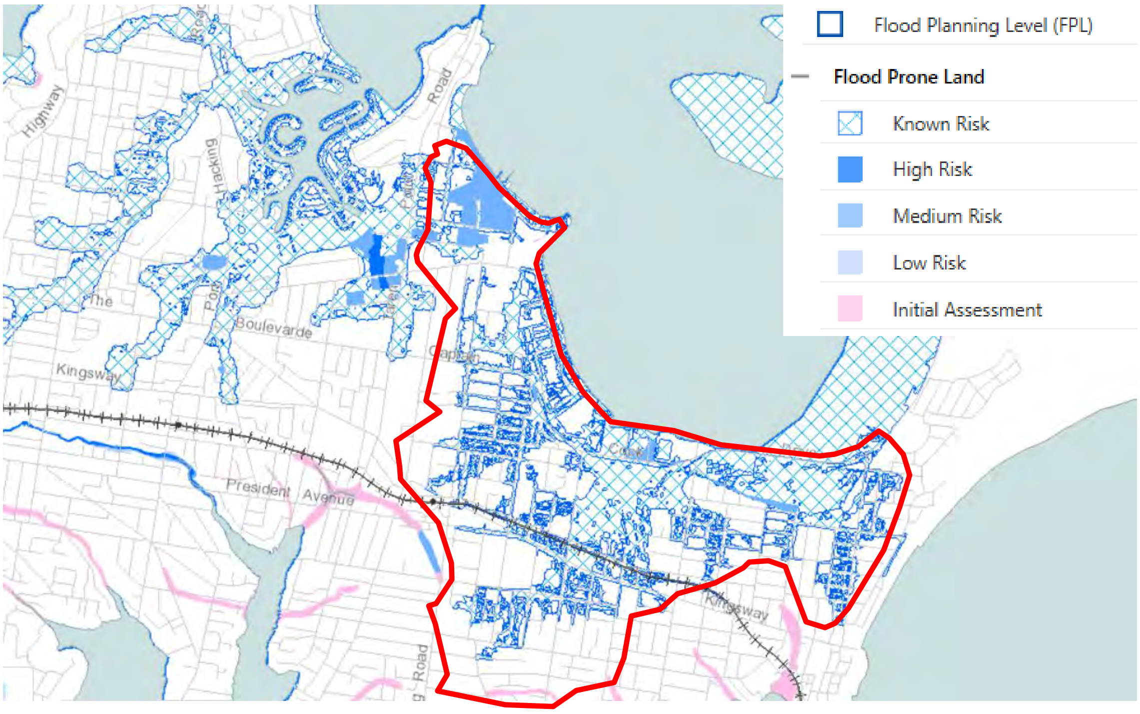
- There are superfluous and sometimes unnecessarily complex provisions, as specifically identified within Appendix C. There is scope to simplify the planning matrix by for example removing subdivision and tourist land use categories and addressing these development types in other ways. Further, the wording of the DCP provisions, including definitions, requires review having regard to current higher order planning instruments and practices, to provide improved clarity.

- The type and stringency of development controls that would be relevant in response to overland flow flooding hazards would mostly be different to those relevant to riverine flood hazards. This can lead to issues when assessing development applications. Consideration of the how the DCP controls apply to riverine flooding and overland flow flooding is undertaken later in this report.

- There is a need to provide a clearer and more direct path to determine if a flood impact assessment is needed to enable the assessment of an individual development application. Additional technical engineering guidance in an Environmental Specification would assist in resolving this.

- Most importantly there is a need to refine and rationalise the DCP flood maps. This needs to be undertaken in conjunction with the several flood map sources available in Council, that are currently available and used for planning purposes. The review of the flood maps will need to resolve the differing extents of mapped flooding as provided by the DCP, Councils on-line mapping and the more detailed FRMS&P mapping, and the need to incorporate mapping relevant to triggering planning controls for overland flow flooding (which can differ from riverine flooding).

The management options section of this report will outline recommendations to address the above issues.



Source: Sutherland Council Online Mapping

Figure 9: Council On-line Flood Mapping

4.12 Developer Contributions

A development contributions plan (**CP**) could provide a potential funding mechanism to contribute towards the costs associated with mitigating flood risks where required to facilitate new development.

Council has both s7.11 and s.7.12 (formerly s.94 and s.94a) CPs. These plans contain some flood mitigation works in the LGA.

A s7.11 CP establishes a process for Council to require development contributions, as a condition of a development consent, towards the funding of basic facilitates required by development and/or the incoming population of that development. The types of facilities are typically open space, community facilities, roads and transport related facilities, and water management works. The facilities are normally of a scale and nature that could not be provided by individual developments (e.g. playing fields or a catchment detention basin). A direct nexus between the proposed works and the development is required.

A s7.12 CP is based on levying contributions on a percentage of development costs. The contributions must be spent on facilities required within the area to which the plan applies but no nexus between that development and the need for the facility is required.

The s7.11 CP applies to all development on land in the south eastern part of the study area, being the area south of Hume Road covering mainly land zoned R4 High Density Residential and B3 Commercial Core. There are no works under this CP currently proposed for the study area.

The S7.12 CP applies to all development in the LGA that is not subject to the s7.11 CP. No works proposed under this CP are located within the study area. Works that are located in Gwawley Bay catchment study area, that drains to Woolooware Bay, are shown in **Table 4**. These works were transferred to the current s7.12 CP from a superseded CP.

Table 4: S7.12 CP Works Within Study Area

Area	Project ID	Title	Project Description	Cost Estimate	Scheduled Completion	Proportion Funded
7.12 Development Contributions Plan 2016						
Various	SW3	Flood Mitigation and Water Quality Treatment	Flood Mitigation and Water Quality Treatments at Production Road. The project at this location will include measures such as widening of existing adjoining Production Road between Bay Road and Woolooware Bay and establish saltmarsh plantations	$2,500,000	2025	100%

Increased development results in increased hard stand areas and additional run-off. Existing stormwater infrastructure may be needed to accommodate the anticipated increase in stormwater flows. In some cases, flood mitigation measures may be required to facilitate urban development. Such works can qualify for inclusion within a CP.

Despite the above, there would likely be limited scope to include flood mitigation works within the S7.11 CP. Minimal flood mitigation works are likely to be required or viable in the study area and this is expected to be a similar situation within the other areas which the CP applies. Further, if works were proposed under this CP, that proportion of the costs that relate to addressing existing flooding problems would be expected to be funded directly by Council or government grants, unless it could be shown that future development will exceed the threshold which triggers the need for the works.

The more appropriate CP for the inclusion of flood mitigation works, would be the s7.12 CP. Inclusion in this CP would not obligate Council to pay for a proportion of the costs of the works that addressed existing problems. However, funds generated under that plan are limited. Any flood mitigation works included in that CP would compete with Council's ability to funder other types of works. Accordingly, inclusion of works in this CP would need to be a whole of Council decision.

There could also be scope for dual use of public open space and public domain areas for drainage purposes, subject to satisfying relevant safety and engineering design considerations

4.13 Section 10.7 Planning Certificates

A s10.7 (formerly S149) Planning Certificate is basically a zoning certificate issued under the provisions of the EP&A Act that is generally available to any person on request but must be attached to a contract prepared for the sale of property. The matters to be contained within the s10.7(2) Certificate are prescribed within Schedule 4 of the EP&A Regulation and generally relate to whether planning controls (and not necessarily flood related risks) apply to a property.

A Section 10.7(5) Certificate, being a more complete but marginally more expensive certificate, requires councils to advise of "other relevant matters affecting the land of which it may be aware". These more complete certificates are not mandatory for inclusion with property sale contracts – a Section 10.7(2) Certificate being the minimum required. Where a Section 10.7(5) Certificate is obtained, this would require a council to notify of all flood risks of which it is aware.

The requirements of the EP&A Regulation regarding the content of s10.7 Planning certificates, as recently amended, was discussed above at section 4.5 of this report.

It is recognised that S10.7 certificates should not be solely relied upon as community education tools as they have only limited circulation. The majority of flood-affected properties would not be reached in a given year. However, information on a S10.7 Certificate can reflect readily available information that may also be provided to people making general enquiries, and are important sources of information for the community that influence what is the understood (or perceived) flood risk of property that a person owns and/or occupies or operates a business from.

Council also provides "Flood Information Sheets" at a fee in response to a formal "Application for Flood Information". The information can be sought by any individual (i.e. it is not restricted to the landowner) and is tailored to provide flood data that enables the controls in the DCP to be addressed. **Figure 10** is an example of the information provided.

This information was made available to Council from the "Kurnell Township Floodplain Risk Management Study" prepared by WMAwater dated 2009.	
FLOOD RISK (SSDCP 2015):	Medium to High
5% AEP:	2.50m AHD to 2.70m AHD
1% AEP:	2.70m AHD to 2.90m AHD
PMF:	3.20m AHD to 4.00m AHD
Minimum habitable floor level*:	1% AEP + 500mm freeboard
Minimum finished floor level (garage and driveway access)*:	1% AEP + 200mm freeboard
Existing Floor Level:	Not available

Figure 10: Extract from Example Flood Information Sheet

The example provides a minimum and maximum flood level (based off AHD) which reflects changes across a sloping site. "Medium to High" refers to the FRPs in the DCP, but include the Low FRP where relevant.

With the existing system of notifications on S10.7(2) certificates, if no notification appears, then it is often misunderstood to mean that a property is "flood free" rather than there are no flood related development controls. For flood risk management purposes, S10.7 certificates should not confuse or mislead those people, with regard to understanding whether there are any risks of floods affecting a particular property.

The FDM defines flood liable land as all land potentially affected by inundation during a flood, up to the PMF. This includes both riverine flooding and flooding from major overland flow paths. Flood mapping prepared as part of this FRMS&P will identify the areas subject to flooding in the study area, up to the PMF.

It is often unreasonable to expect that a Council will be able to unequivocally confirm that they have mapped all areas subject to potential flooding (mainly due to the unreasonable resources that would be required to accurately map all overland flow paths). We understand that Council is continuing to undertake studies, such as this subject FRMS&P, to fill such information gaps, and continuation of this work is an important FRM initiative. The absence of such information was identified as a key issue by council's development assessment planners due to problems caused with the identification of flood constraints on a property midway through the DA assessment process.

The information regarding flood risk provided with a s10.7 Certificate, would not in itself lead to any alteration to the permissibility of development but is directed towards providing factual information known to Council (important due to liability issues) to increase awareness of the potential flood risks and to provide full and consistent messaging about flood risks.

At the time of preparing this report Council was in the process of reviewing flood related notations on s10.7 Planning certificates, as a consequence to the recent changes to the EP&A Regulations associated with the Flood Prone Land Package. Prior to this, there were no issues identified in regard to Council's approach to issuing s10.7 certificates or Flood Information Sheets.

However, with the changes brought about by the 2021 Flood Prone Land Package it is now open to Council to reconsider the way the LEP and DCP provisions apply through the defining of FPL/FPA. This is discussed later in this report.

4.14 Fencing

Fences can impact overland flow flooding and redirect flows during a storm event into properties or impact access and evacuation paths.

Chapter 40 of the DCP does not contain controls on fencing on flood prone land. Despite this Council advises that a requirement for flood compatible fencing is often included as condition of development consent. However, monitoring of constructed fences over time is difficult, resource demanding and consequently unlikely to occur.

The Codes SEPP provides several paths for landowners to construct new fences as exempt or complying development. Clauses 2.33 and 2.34 detail the requirements for fences in certain residential zones and the RU5 zone under an LEP. Clauses 2.37 and 2.38 detail the requirements for fences in business and industrial zones.

Fences on Residential Land

Clause 2.33(c) under the Codes SEPP excludes fences from being built as exempt development on a flood control lot. Therefore, if a lot is subject to a flood related development control, a fence cannot be pursued as exempt development on residential zoned land.

It is envisaged that the general public is unaware that fences on flood controls lots require a full DA.

Fences on business and industrial land

As with fences on residential lots, Clause 2.37 of the Codes SEPP excludes fences on a flood control lot zoned for business or industrial purposes. However, Clauses 5.23 and 5.24 of the Commercial and Industrial Alterations Code allows a fence to be approved as complying development but only if:

- it is on a side or rear boundary
- not be any higher than 3m above the exiting ground level
- cannot be of a solid construction (e.g. a wire mesh fence).

Subclause 5.24(2) of the Codes SEPP also requires any fence along a site boundary that adjoins a residential zone or a lane to have a design that is 75% open for that part of the fence that is more than 1.8m above ground level.

AS required by our brief we later consider opportunities to formalise requirements for flood compatible fences as part of the assessment process including an approach to achieve consistency between the Codes SEPP, *Dividing Fences Act 1991* and possible voluntary fence modification schemes. We have excluded situations where retaining walls are proposed in conjunction with a boundary fence, which introduces additional approval considerations that would normally trigger a requirement for a full DA which would allow for a site specific assessment of any flood implications.

4.15 Flow Paths and Drainage Easements

The primary benefit of an easement could be to alert property owners that it is not appropriate to locate structures in locations where they would affect flood flows. This could discourage unauthorised development in such locations (e.g. sheds, retaining walls, etc), prevent inappropriate development occurring by way of exempt or complying development provisions and provide an additional trigger for Council's consideration when assessing a development application.

In addition to easement related issues Council identified concerns with situations where overland flow is allowed to pass directly under a new building. Although the development may technically comply with floor level and flood effects controls, there are concerns regarding the emotional and possible health impacts (such as mould, odour and rubbish accumulation) associated with intermittent concentrated flow through a sub-floor space. The existing DCP controls do not address these situations. Consideration as to whether such matters should be addressed by the DCP or preferably within complementary Environmental Specifications, as discussed later in this report.

Issues associated with drainage easements can relate to both stormwater drainage and overland flow flooding. Council's 2009 Stormwater Specification addresses stormwater drainage, and this is beyond the scope of this report.

The extent of overland flow flooding, as would be the case with flooding in general, would not normally be delineated within an easement imposed as a restriction on the title of a property. There are consequently no currently documented processes in Council to trigger the need for and then to create, modify or extinguish drainage easements to recognise an overland flooding flow path.

The exception would be in situations where a pipe is provided in association with an existing or proposed development to convey all or a proportion of stormwater flows and an easement is created for the pipeline together with an easement to cater for excess overland flow during a significant storm event and/or in case of blockage. This would be consistent with standard practice in our experience as it would be unrealistic to expect that the overland flow associated with a large flood (such as a 1%AEP event) can be contained within an easement, particularly for wide flat flowpaths.

Consideration for the need of an easement for an overland flow path arises because development of any type that creates an obstruction to the flow path of overland flooding, can alter the behaviour of the flood flows in a way that impacts on other properties. This is typically not an issue where a development application is required which is assessed by council with the benefit of flood mapping such as that prepared for this FRMS&P. In that case Council has the opportunity to identify and assess the situation to ensure that the development does not have an unacceptable impact.

Where historically a piped drainage system has been installed but no easement had been created for the pipeline or overland flow path (if needed) then Council should use its best endeavours to create an easement. The purchase of such easements could incur a requirement for compensation to be paid. Consequently, Council should preferentially seek to negotiate the dedication, without compensation, of historically required easements to ensure ongoing FRM protection, when opportunities present (such as when considering a planning proposal or development application).

If there are problematic areas where if flow paths are blocked this consequently has flood impacts on properties, Council could consider attempting to acquire the easement by way of a negotiated settlement. The purchase of an easement would need to be considered in conjunction with the need to remove or relocate any structures located within such a proposed easement. The benefit of reducing flood impacts would need to be assessed to justify inclusion as a final recommendation of the FRMS&P.

The power to revoke or modify such easements should rest with Council. Where a landowner seeks to build over or encroach into a Council easement, they would be required to demonstrate there is no net increase in flooding impact. Typically Council would only allow minor development within easements such as driveways, landscaping and carports (provided they can be dismantled).

5 Management Options & Recommendations

5.1 An Overall Framework

5.1.1 General Principles

The primary objective of the NSW Government's Flood Prone Land Policy is to "reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property" and to "reduce private and public losses resulting from floods". At the same time, the policy recognises the benefits flowing from the use, occupation and development of flood prone land.

The only way to completely remove flood risks from a development is for it to be located outside the extent of the PMF. That would be a very risk-averse approach to floodplain management which is not supported by the FDM. One of the principal tenants of the Flood Prone Lands Policy[15] is that "flood prone land is a valuable resource that should not be sterilised by unnecessarily precluding its development".

When considering future development, both the Policy and the FDM promote the use of a "merit approach" which balances social, economic, environmental and flood risk parameters to determine whether particular development or use of the floodplain is appropriate and sustainable. In this way the policy avoids the unnecessary sterilisation of flood prone land. Equally it ensures that flood prone land is not the subject of uncontrolled development inconsistent with its tolerable exposure to flooding.

As a general rule, almost any development involves some risks to property or people. For example, construction of a new subdivision introduces traffic risks which may be managed (e.g. through construction of traffic lights, signage, etc) but are not completely eliminated. Rather the risks are reduced to a level which is considered acceptable to the community. Flood risks are managed in a similar fashion. Nevertheless, in some situations if the residual risks remain unacceptably high, alternative safer forms of development should be pursued.

Consequently, best practice FRM in planning involves applying a risk management approach. This requires an understanding of risk management principles and their application to FRM, as discussed below.

5.1.2 Understanding Flood Risks

Within the context of this report, 'flood risk' is defined as the combination of probabilities and consequences that may occur over the full spectrum of floods that are possible at a particular location.

It is important not to confuse 'flood risk' with 'flood hazard' or 'provisional flood hazard'. The terms 'hazard' and 'provisional hazard' are defined in the FDM and are associated with the magnitude and behaviour of a specific flood. For example, a site may experience high hazard conditions in a 100 year flood and low hazard conditions in a 5 year flood. On the other hand, the term flood risk used

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[15] FDM,2005, pg.1.

in this report does not relate to a single flood, but rather to all floods. It presents a single measure of a site's exposure to all its flood threats.

As flood risk combines all the probabilities and consequences of flooding over the full spectrum of flood frequencies that might occur at a site, it can be expressed in mathematical notation as follows:

$$\textit{Flood Risk} = \int_{\textit{all floods}} \textit{Probability x Consequence}$$

where probability is the chance of a flood occurring, and consequence is the property damage and personal danger resulting from the site's flood characteristics.

In order to understand the severity of flood risk, it is therefore necessary to consider the potential hazards that can occur to people and property in various flood magnitudes which have different probabilities of occurrence. To assist in this task, a range of analyses have been undertaken as part of the FRMS&P as discussed above and in the main WMA report.

5.1.3 General Approaches for Managing Flood Risks

There are three principal options for managing flood risks:

1. **avoiding the risk** (property modification measures) – land use zoning is the key management option by which flood risk is avoided. Inappropriate flood risks can be avoided by ensuring that only development compatible with the flood hazard is located in the floodplain;
2. **reducing the likelihood** (flood modification measures) – construction of detention basins, levies and other structural measures can reduce the probability of flooding; and
3. **reducing the consequences** (property modification and response modification measures)– with a range of measures including:

    - setting floor levels and other development controls
    - using flood compatible building materials and methods
    - ensuring buildings are structurally sound if exposed to flooding
    - raising flood awareness amongst communities
    - improved emergency management
    - improved flood warning
    - transferring some of the consequences to others through insurance
    - provision of disaster relief and past flood recovery programs.

In every situation, avoiding the risk through effective land use planning is the preferred option, if possible. Nevertheless, pressures for land development, the lack of suitable land outside the floodplain, and a range of other non-flood related opportunities and constraints mean that use of some floodplain land may still be the best option for the community. The FDM guides Councils and consent authorities to use the 'merit approach' in making these land use decisions, balancing flood risk with other social, environmental and economic considerations.

As flood risk comprises risk to property and risk to life, the management of flood risk considers options for managing both the risk to property and risks to personal safety.

5.1.4 Risks to Property

The most common method of reducing the consequences to property is by controlling the height of floor levels relative to a given probability flood. A range of flood planning levels (FPLs) are usually established by councils for this purpose that relate to different land uses and different building components (e.g. habitable floors, non-habitable floors and car parking). Research associated with other FRMS&Ps we have been involved with has identified that a community would typically accept higher levels of property damage for rural and recreational buildings as opposed to community uses such as hospitals and schools.

Traditionally the 100 year flood (plus freeboard) FPL has been considered to be an acceptable level of risk for most residential, commercial and industrial properties in NSW. However, this standard can vary if justified for some land uses or components of development and need not determine the land extent that is zoned for development. In some cases, mitigation measures such as filling could extend the area of a floodplain that can be acceptably developed. Conversely, development of less of a floodplain might be considered appropriate due to issues such as unusually high flood depths and consequent flood damages, evacuation constraints or predictions of reaching thresholds of unacceptability due to climate change.

In addition, other complementary controls are used to manage property risks including the use of flood compatible building materials and methods as well as ensuring buildings are strong enough to withstand the forces of flood waters without collapse. These types of controls are discussed as part of the DCP recommendations.

5.1.5 Risks to People

Risk to life should be seen as a key flood constraint when undertaking strategic planning for potential new development. Planning can assist in managing risks to people with a range of measures including recognising evacuation and emergency management constraints, and increasing the community's awareness and preparedness for flooding.

Consideration of flood risks to life is a requirement of the both the newly introduced standard and SFC LEP flood clauses. More detailed considerations are discussed as part of the DCP recommendations. The following provides general principles for consideration for planning purposes.

Emergency management is a principal mechanism that requires consideration within the planning process as it can influence the:

- **location of new development** – in areas free of flood risk or where evacuation away from the flood risk is possible

- **type of development** – for example developments such as seniors housing and child care centres can have limited capacity for self-evacuation and may induce risky action with guardians seeking to travel into flood affected areas to retrieve seniors or children.

- **form of development** – so that it is designed to allow for pedestrian and/or vehicular evacuation, and buildings that are structurally resilient to the forces of floodwaters if unavoidably required to provide a refuge

- **connections between developments and safe refuges or support facilities** – to ensure that pedestrian paths and road systems are designed to facilitate evacuation and access to safe refuges, support facilities and/or evacuation centres.

The evacuation risks are determined by considering the flood characteristics of the site together with its topography, its proposed uses and demographics of its occupants, and the capacity of evacuation routes.

Where practical, evacuation is preferable for residents subject to potential inundation. The purpose of evacuation is to temporarily relocate persons to places of safety beyond the floodplain prior to the onset of flooding. However, the risks involved in evacuation require assessment, as evacuation may not always be the most appropriate action. The assessment should consider whether people could be exposed to more hazardous environments as a consequence of their evacuation, for example, travelling through deep and/or fast-flowing floodwater[16]

Sheltering in place may provide a disincentive for communities to evacuate if required by authorities and may be subject to other risks. An issue encountered by people who take refuge in such facilities is the potential isolation. Isolation can be accompanied by additional safety risks to the occupants including the inability to reach medical assistance, lack of food, sanitation, potential for additional fire risks, isolation induced trauma, and exposure to extremes of temperature. Importantly, sheltering in place requires a safe refuge that is not in danger of being inundated or structurally failing.

In flash flood situations, where there is minimal warning time, the comparative risks can warrant sheltering in place over offsite evacuation, where a safe onsite refuge is available. Consequently, in some situations a requirement for elevated on-site refuges for sheltering in place can be warranted as a means of addressing evacuation considerations in the assessment of applications for new development.

A suitable refuge would provide a safe haven above the reach of flood waters, that was structurally sound in all possible flood situations (ie up to and including a PMF) and provided adequate space and facilities to sustain the likely occupants of the building for the period of time that they are likely to be isolated. This could also provide a space where valuable goods and personal memorabilia can be stored. Such facilities need to ensure the health and safety of occupants for the likely duration of flood emergencies and must recognise the age, health, mobility, medical needs and the level of resilience of the occupants.

At present the flood warning time in the Woolooware catchment is approximately 6 hours, albeit with the potential for future improvements. Such a relatively short warning time is characteristic of overland flow flooding. The flood modelling prepared by WMA indicates the potential for hazardous

[16] *Flood Emergency Planning for Disaster Resilience*, AIDR, 2020, pg.26

road conditions during major floods. Consequently, requiring safe refuges for sheltering in place for new development located within the floodplain is considered an appropriate planning response to support emergency management in the study area.

The DCP presently requires the following for all development in the floodplain, except development in the "Recreation and non-urban" land use category:

> *Reliable access for pedestrians or vehicles shall be provided from the building commencing at a minimum level equal to the lowest habitable floor level to an area of refuge above the PMF level.*

Reliable access is defined as:

> *Reliable access during a flood means the ability for people to safely evacuate an area subject to imminent flooding within effective warning time, having regard to the depth and velocity of flood waters, the suitability of the evacuation route, and without a need to travel through areas where water depths increase.*

While potentially ambiguous, this provision could be satisfied by either demonstrating that evacuation to a refuge outside of the floodplain could be achieved within available warning time or the provision of an site refuge with a floor level above the PMF. This is considered to provide an appropriate control to address flood evacuation for DAs that might be encountered across the different floodplains in the LGA, including Woolooware. In addition to clearer wording, the provisions could include a definition for a safe refuge that specifies:

- minimum floor area per expected occupant (eg minimum 1-2m^2 per person) and adequate facilities to sustain the likely occupants of the building for period of time that they are likely to isolated

- the refuge is to be part of a building certified by a suitable qualified engineer as capable of withstanding the forces of floodwater, debris and buoyancy up to and including a PMF.

While not specifically relevant to the study area, in addition to the above DA measures, Council should review potential evacuation issues as part of any strategic planning exercise associated with the possible growth of an existing area. The review should ensure that where practical there would be adequate capacity in the road network so that people could evacuate a flood affected area or that sheltering in place would be an acceptable strategy.

5.2 Process Improvements

The best ways to improve flood planning related processes involves:

- plan making - provide guidance to ensure that flood risk is properly considered at the strategic planning stage

- plan implementation - make planning controls simple and clear.

Ways to achieve the above are discussed below.

5.3 Flood Maps for Planning Purposes

The flood maps and information contained in the FRMS&P (and Flood Study) provide an invaluable source of information that can be used to understand flood risk management considerations.

The strategic planning process requires the consideration of a wide range of factors to produce or review plans that guide land use management and development in an area. FRM is one of these factors. The type of flood risk information that can be extracted from a Flood Study and FRMS&P and mapped for use for strategic planning purposes differs from flood planning maps prepared to be read in conjunction with an LEP or DCP. The differences relate to their function.

Strategic Planning

The extent of flood information and mapping that can be used for strategic planning purposes can be more complex compared to that needed for statutory planning purposes, but ultimately needs to be fit for purpose. The flood information might include hazard (i.e. depth and velocities), hydraulic categorisation (i.e. flood fringe, flood storage or floodway), evacuation constraints and variations with projected climate change. This should be considered for a range of floods so that the full spectrum of flood risk can be understood. A system to distil this type of information into maps that can be used for strategic planning purposes is the flood planning constraint categorisation approach outlined by *Guideline 7-5 Flood Information to Support Land-use Planning.* This is a supporting document for *Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (Australian Institute of Disaster Resilience – AIDR, 2017).

Guideline 7-5 provides a basis for a simplified grouping of flood risk information across a range of flood frequencies into flood planning constraint categories (**FPCC**s). This information includes a single map (or map series) outlining FPCCs and information on the implications of flooding in the different FPCCs. This information can be used to inform the preparation of strategic plans (such as Council's Local Strategic Planning Statement) and LEP zone boundaries.

Importantly there is no impediment to using an approach such as FPCCs to guide the delineation of zone boundaries. Any single FPL need not be the basis for determining zone boundaries.

Statutory Planning

The function of flood planning maps prepared for statutory planning purposes is to trigger approval pathways and FRM considerations to be addressed in the assessment of a development proposal. For example, such mapping could identify where development cannot be processed through a complying development pathway because it located on land subject to one or more of the five hazardous conditions referred to in the Codes SEPP. Also, the mapping can differentiate land mapped as low flood risk where no planning controls, other than evacuation considerations, apply to standard residential development. Further the mapping could (if necessary) trigger specific matters to be addressed, such as the need for more detailed modelling to assess flood impact in parts of a floodplain. This type of mapping is akin to that currently relied upon by Councils DCP which maps low, medium and high flood risk precincts.

In order to simplify the planning process and provide greater clarity, it is necessary to rely on flood mapping that separately addresses the different functions required by the strategic planning and statutory planning processes.

5.4 Strategic Planning Input

In the context of the study area, and most of the LGA in general, the use of FPCCs needs to be tailored to provide guidance on whether existing urban zones can be intensified and if so what flood mitigation related works or infrastructure is required to ensure acceptable risks. Ultimately the acceptability of flood risk, and required responses to ensure acceptable risk, will need to be considered together with the range of other relevant planning considerations, to determine the preferred planning outcome.

Table 5 outlines how FPCCs could be used to inform the strategic planning process in the LGA. Note, while the relevance of this information to the study is variable (eg there are only very small areas of H6 in the study area and all are effectively in public roads) the table has been prepared as general reference for use across the LGA where different types of flooding may be experienced. Further, the range of considerations identified in the table could be reviewed and refined by Council over time applying specialised and local flood engineering knowledge, that is beyond the scope of this planning report.

Table 5: Inputs for Strategic Planning Purposes

Flood Planning Constraint Category[17]	Planning Implications	Potential Planning Response
1 Flow conveyance and storage areas in the 1% AEP flood and • H6 hazard in the 1% AEP flood	<u>Riverine Flooding</u> Likely to have material flood impacts on other properties in the floodplain. Unsafe for vehicles and people. All building types are considered vulnerable to structural failure. <u>Overland flow Flooding</u> Assuming basic building envelopes, minor increases in building footprints within established urban areas is unlikely to have significant impacts. Major changes should be tested with flood modelling. Generally expected to be less hazardous than in areas subject to riverine flooding. Implications for structural stability and personal safety can be reviewed based on hydraulic hazard. New buildings can divert flows to have impacts and may require testing with flood modelling.	• Consider whether development can be master-planned to avoid locating buildings or pedestrian/vehicular trafficked routes in these areas. Adjust controls such as minimum lot size standards or impose specific controls to ensure the desired outcome (such as no adverse impact on flood flows) would be achieved. • Review potential cumulative impacts (i.e. is the proposal confidently an isolated situation or whether cumulative impacts would exacerbate impacts). • Consider where flood impacts would occur and if they could be potentially addressed with acceptable engineering solutions or setbacks that would leave sufficient feasible development potential. • Consider likely emergency management response, nature of use and robustness of likely building form (e.g. whether adequate warning time allows for evacuation or shelter in place is expected and whether building form is

[17] H1 to H6 are references to the hazard mapping categories outlined in Handbook 7 (AIDR, 2017) and mapped by WMA as part of the FRMS&P.

Flood Planning Constraint Category[17]	Planning Implications	Potential Planning Response
		readily capable of being made structurally sound in expected floods). • In areas subject to only overland flow flooding, or short duration riverine flooding, shelter in place is likely to be an acceptable planning response for emergency management. In other areas the evacuation capability of the area should be reviewed and if required coordinate delivery of augmented evacuation routes with new development.
2 Flow conveyance in events larger than the 1% AEP flood and • Flood hazard H5 in the 1% AEP flood • Emergency response—isolated and submerged areas • Emergency response—isolated but elevated areas • Flood hazard H6 in floods larger than the 1% AEP flood	Riverine Flooding While frequency could be less, a flood larger than the 1% AEP flood would impact development with significant consequences for building damages and life. Unsafe for vehicles and people. All building types are considered vulnerable to structural failure. Area becomes isolated by floodwater or impassable terrain, with loss of evacuation route to the community evacuation location. The area will become fully submerged with no flood-free land in an extreme event, with ramifications for those who have not evacuated and are unable to be rescued. Overland flow Flooding Overland flow floods larger than the 1% AEP are unlikely to have materially greater flood depths than a 1% AEP plus freeboard. The primary implication could be additional impacts on evacuation routes. There are likely to be no or minimal warning times and therefore shelter in place could be a reasonable emergency management response.	• Avoid development types that are less likely to cope with unexpected flood flows (e.g. low rise residential, child care centres, exposed ground level shops, etc.). • Consider nature of use and robustness of likely building form. • Determine whether there is adequate warning time and availability/capacity within roads or pedestrian routes to evacuate the affected population. If required, consider whether sheltering in place would be acceptable or evacuation capacity should be augmented by providing new or enlarged evacuation routes and how that would be delivered and timing (e.g. through a forward funded development contributions scheme or as a condition of development consent).
3 Outside FPCC2—generally below the 1% AEP flood	Riverine Flooding Hazardous conditions may exist creating issues for vehicles and people. Structural damage to buildings that meet building standards unlikely because of flooding.	• Ensure development with required FPLs can be acceptably delivered e.g. floor levels and overall building heights would produce acceptable streetscapes and amenity outcomes.

Flood Planning Constraint Category[17]	Planning Implications	Potential Planning Response
	Overland flow Flooding Most land uses could be acceptable provided that buildings can be sited outside of flow paths or flood flows are manageable with engineering measures.	• That parking areas, particularly basement car parking can be adequately protected from inundation. • Provide appropriate detail controls in DCP to ensure the residual risks to buildings, life and the environment are managed (generally by the range of controls within the existing DCP subject to any recommended changes from this and subsequent FRMS&Ps). Consider a lower freeboard for overland flow flooding where depth of flooding is low relatively to a standard 0.5m freeboard. • Consider the need for additional or augmented infrastructure for emergency response facilities, key community infrastructure and vulnerable potential occupants in the floodplain, and appropriate delivery mechanisms. • Development options may require testing to ensure they are achievable without impacting others. • Development options may require testing to ensure feasibility (e.g. structural integrity of buildings can be assured with reasonable engineering). This is unlikely to be an issue in areas subject to only overland flow flooding.
4 Outside FPCC3, but within the probable maximum flood (or similar extreme event).	Riverine Flooding Emergency response may rely on key community facilities such as emergency hospitals, emergency management headquarters and evacuation centres operating during an event. Recovery may rely on key utility services being able to be readily re-established after an event Overland Flow Flooding As for FPCC 2.	• Avoid zoning that promotes development in these areas for key community facilities or vulnerable land uses (such as seniors housing) and critical facilities. In areas affected by only overland flow flooding seniors housing is expected to be acceptable. • Ensure these areas are recognised in planning documents as subject to flood risk (albeit low) and may be subject to evacuation. • Consider the need for additional or augmented infrastructure for emergency response facilities including upgrading roads for evacuation purposes, key community infrastructure and vulnerable potential occupants in the floodplain, and appropriate delivery mechanisms.

The application of the principles in Table 5 requires a further climate change layer of consideration. A sensitivity analysis assuming sea level rise and rainfall variation projections should be undertaken as part of the planning process if not already undertaken through the Flood Study of FRMS&P processes.

In regard to parts of the LGA such as the study area, sea level rise considerations can be accounted for through an increase in floor level FPLs for those properties affected by coastal inundation. Potential increases in rainfall intensity could be factored into any future technical flood engineering assessment of freeboard.

While climate change flood risks are not forecast to have significant implications to developable land within the study area, there are other parts of the LGA where the implications are likely to be significant. The strategic planning process should take into consideration climate change flood risks by applying a precautionary approach. Where the sensitivity analysis shows that there are potentially significant additional risks, and the totality of the flood risks would be beyond that which would otherwise be considered acceptable or manageable, then the considerations in Table 5 should be subject to sensitivity testing based on FPCCs generated using possible projected climate change factors.

There are low lying coastal areas within the LGA where planned retreat or long term redevelopment options may warrant consideration. Such considerations are beyond the scope of this study, but there will be a need to consider the practicality of a protection response (e.g. sea walls and levees) into the long term, as opposed to planned retreat or wholescale redevelopment[18]. These considerations would be relevant in areas where an adaptation strategy, involving the community, is warranted.

5.5 Changes to the FRM Statutory Planning Framework

5.5.1 The Overall Framework

Traditionally, the FRM statutory planning framework is based on determining a singular FPL to determine the extent of an FPA which in turn governs the appearance of statutory flood planning maps and how FRM controls are applied across an area.

Our experience with FRM statutory planning frameworks established for LGAs across NSW are they are overly complex. Additionally, while FRM planning controls are not expected to remove all flood risks from all types of development they typically poorly communicate to the community the residual risk. The complexity of the system results in unnecessary costs and delays in the assessment of DAs and inadvertently can mislead the community about actual flood risk and potentially diminish preparedness in times of significant floods.

The preceding sections of this report outlined the existing policy framework that applies in NSW and the FRM planning controls currently applying in the study area and LGA. To better understand how the NSW Policy framework has been historically applied we analysed 49 LGAs in the Sydney Metropolitan, Illawarra and Hunter regions of NSW prior to any changes initiated in July 2021 associated with the Flood Prone Lands Package, and summarise our findings in **Table 6**.

[18] Whole scale redevelopment is where redevelopment of all buildings and infrastructure (in particular roads) is undertaken which provides the opportunity to provide filled raised ground levels and more reliant development design and construction.

Table 6: Analysis of FRM Planning Controls adopted by Other Councils[19]

Planning Outcome	Total No. of Councils	Percentage of Councils
Adopts model Flood LEP Clause or similar	41	84%
Of the LEPs that adopted a Flood LEP clause; Defines flood planning level as follows: *flood planning level means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard*	32	78%
Adopts additional Floodplain Risk Management clause	6	15%
Includes LEP Flood Maps	19	46%
Adopts DCP FRM Provisions	36	88%
Includes Flood Maps in DCP	9	22%
DCP adopts multiple Flood Risk Precincts/Areas	13	32%
Adopts standalone Flood Maps or Studies	33	81%

The above analysis demonstrates that historically there is a lack of conformity across urban councils within NSW. While the July 2021 Flood Prone Land Package changes create potential to remove these inconsistencies, the full extent of changes that are to be undertaken by Councils, particularly in regard to DCP and mapping changes, are yet to fully understood. Despite what has been the traditional approach, Sutherland Council should not be inhibited in formulating the optimum FRM statutory planning framework for its LGA, particularly due to the flexibility and responsibility provided by the 2021 Guideline which requires Council to determine FPLs and FPAs having regard to the local circumstances.

The FDM (pg.21) defines FPLs and flood planning area (FPA) as follows:

flood planning levels (FPLs) *are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the "standard flood event" in the 1986 manual.*

flood planning area *[is] the area of land below the FPL and thus subject to flood related development controls. The concept of flood planning area generally supersedes the "flood liable land" concept in the 1986 Manual.*

Consistent with the above definition, and now consistent with the 2021 Guideline, the FDM facilitates the adoption of multiple FPLs. This is current best practice as it would allow the adoption of different FPLs to target different components of a development (e.g. habitable, non-habitable floors,

[19] Note, the table excludes the Growth Centres SEPP.

carparking, entry to basement car parking, private open space, etc) as well as managing different land uses with different vulnerabilities to flood hazards (e.g. seniors housing, standard residential or commercial/industrial). Different FPLs can also be used for other purposes such as to define the standard to which buildings need to be certified as structurally sound, the level at which flood compatible materials need to be installed, or the extent of the floodplain to be considered when assessing external flood impacts. This enables the application of a risk management approach to planning.

However, the definition of flood planning area (**FPA**) implies the adoption of a single 'flood planning area' for planning purposes which had in past years become common practice, but is not best practice or the only approach adopted by other planning authorities across NSW or Australia.

Consequently, the preferred and recommended approach is to continue to adopt multiple FPLs and flood planning maps with a series of flood risk precincts (**FRP**s) consistent with the approach adopted by Council's existing DCP. The aggregated area covered by the flood risk precincts is effectively the PMF. Consequently, as discussed below we also recommend that the FPA be defined as the extent of the PMF.

As discussed later, recommendations are also provided to simplify the number of flood maps prepared. Overland flow flooding can be mapped with FRPs similar to the approach taken for riverine flooding. However, the FRM planning controls for overland flow flooding do not need to be as complex as those required for riverine flood risks.

5.5.2 Flood Planning Maps

At present the following flood planning maps exist for use in the statutory planning processes relevant to the LGA:

- the Flood Risk Management Maps in Chapter 15 of the DCP which show high, medium, low and Initial Assessment FRPs, together with the best known extents of the PMF, FPL (i.e. 1% AEP plus 0.5m freeboard) and 1 % AEP flood This mapping notes the existence of the relatively recently completed 2014 Woolooware Bay Catchment Flood Study (as well as other flood studies completed for Gwawley Bay, Kurnell, and Bundeena) without updating the DCP maps.

- Council's *Shire Maps* which provide an online GIS based mapping system that includes a Flood Prone Land layer that shows areas of "Known Risk" together with high, medium, low and Initial Assessment FRPs. This information is more current than that shown on the DCP maps and more extensive than that shown on the LEP maps. The high, medium and low FRPs are defined in the DCP as follows:

    - Low Flood Risk is all land that could potentially be inundated (i.e. within the extent of the probable maximum flood) but not identified as either a high flood risk or a medium flood risk precinct.

    - Medium Flood Risk is the area below the 100 year flood that is not subject to a high hydraulic hazard and where there are no significant evacuation difficulties.

    - High flood risk is defined as an area of land below the 1% AEP flood level that is either subject to a high hydraulic hazard or where there are significant evacuation difficulties.

- flood maps contained in Flood Studies and FRMS&Ps which, for example, can provide information to determine whether land is subject to flood hazards that would preclude a development from being considered complying development under the Codes SEPP.

As discussed above, prior to 14 July 2021 Flood Planning Maps showing the FPA were included in SSLEP. The FPA shown was the extent of the 1% AEP flood plus 0.5m freeboard and not the complete known extent of land potentially subject to flooding. Note, the LEP flood overlay maps, identified the extent of the 1% AEP flood elevated by 0.5m to reflect the maximum freeboard applied by Council. This reflected an area that was not based on an actual flood and was broader than the combined medium and high FRPs which are mapped to include only the 1% AEP extent.

The disadvantages to relying on and maintaining multiple map sets include:

- time and costs required to review and update each map set
- the risk of inconsistencies between the same information on each map set due to transposition errors and different timing for updating
- the potential to confuse the community in regard to the actual known flood risk for an individual property
- negating the opportunity to use the flood mapping to provide a single consistent platform that can be used in promoting flood awareness and preparedness.

LEPs can no longer contain flood overlay maps and based on our review of the policy directions there is no mandatory requirement to provide flood maps within a DCP. Accordingly, our recommendation is to dispense with flood maps within the DCP and to rely on a single map set provided by Council's on-line *Shire Maps.*

While the FRP flood mapping approach is supported, the range of FRPs and the criteria for mapping was reviewed as part of this study. The purpose of this review is to identify and to evaluate any options for refinement.

Having regard to the above, **Table 7** outlines the recommended FRPs, their mapping criteria and commentary on how they would relate to the LEP clause and the Codes SEPP.

Table 7: Proposed Structure for Mapping and Planning Controls

Flood Precinct	Purpose	Mapping Criteria	Relationship with LEP and Codes SEPP
High	That area subject to riverine or overland flow flooding where most development would be subject to significant flood risks. The aim is to avoid intensification within the high flood risk precinct that would increase flood risk. It is expected that there would be difficulties in siting development	Land below the 1% AEP flood level that is subject to high provisional hydraulic hazard (as per the FDM), or is likely to be subject to evacuation difficulties.	This FRP would be part of the area subject to the LEP flood planning clause for all development. Having regard to the factors considered in the preparation of the FRMS&P including Council's experience with applications in the floodplain, land within this area would be included in one or more of

Flood Precinct	Purpose	Mapping Criteria	Relationship with LEP and Codes SEPP
	permitted on land within this FRP (subject to consent) without substantial mitigation measures that in some cases may be unacceptable due to environmental or amenity impacts. In this FRP there is a possible danger to personal safety, evacuation by trucks would be difficult, abled-bodies adults would have difficulty wading to safety, and there is a potential for significant structural damage to buildings. A development application process (as opposed to a complying development approval pathway) would be important to assessing and managing development proposals on land within this FRP.		the five flood constraint categories excluded from a complying development approval pathway under State *Environmental Planning Policy (Exempt and Complying Development Codes) 2008*.
Medium	That area subject to riverine or overland flow flooding where there is significant potential for flood damages and risk to life, but mitigation measures are expected to be able to manage risks to an acceptable level. It is expected that subject to skilful site responsive design, mitigation measures can be implemented to provide an acceptable FRM outcome without unacceptable environmental or amenity impacts. A development application process (as opposed to a complying development approval pathway) would be important to assessing and managing development proposals on land within this FRP.	Land subject to flooding that is below the 1% AEP flood level and not mapped as part of the High FRP.	This FRP would be part of the area subject to the LEP flood planning clause for all development. Having regard to the factors considered in the preparation of the FRMS&P including Council's experience with applications in the floodplain, land within this area would be included in one or more of the five flood constraint categories excluded from a complying development approval pathway under State *Environmental Planning Policy (Exempt and Complying Development Codes) 2008*.
Low	That area subject to riverine or overland flow flooding where most development	Land that could potentially be inundated (i.e. within the extent of the probable	The recent Flood Prone Land Package changes to LEP would allow this

Flood Precinct	Purpose	Mapping Criteria	Relationship with LEP and Codes SEPP
	(in particular standard residential development) would be subject to tolerable flood risk in this precinct, without mitigation measures. A complying development approval pathway would not be excluded for land located within this precinct. Sensitive or hazardous development that is especially vulnerable to flood risks may require flood mitigation measures in order to be acceptable.	maximum flood) but not identified as in either a high or medium precinct. Over time some areas within this precinct might become categorised in higher risk precincts because of climate change.	precinct to be part of the area subject to the LEP flood planning clause for all development. As discussed later, this would allow for the application of the DCP controls without any potential inconsistencies. Land within this area would not be included in one or more of the five flood constrained categories excluded from a complying development approval pathway under State *Environmental Planning Policy (Exempt and Complying Development Codes) 2008*.
Initial Assessment	That part of the LGA where no flood modelling has been undertaken but has been identified as potentially subject to flooding using a rapid assessment methodology. Land in this area is flagged to advise potential applicants and Council assessment officers that further detailed investigations, possibly involving flood modelling, would be necessary prior to proceeding with any development proposal. The mapping of this area also highlights to the general public the qualified possibility of flood issues.	It is not expected that any additional areas will be mapped under this category. As flood modelling progresses within these areas, the mapping should convert to the use of one of the above four precincts or be confirmed as flood free.	Land within this precinct would require further investigation, and if necessary flood modelling, to determine which of the above precincts apply, or whether the land or part of the land is flood free.

It would be desirable if these maps could differentiate between areas subject to riverine and only overland flow flooding. This would assist in the application of variable DCP controls, such as lower freeboard for area subject to only overland flow flooding. This could be achieved by for example delineating areas subject to only overland flow flooding with a distinctive line (eg orange).

As discussed above it is appropriate for flood studies and FRMS&Ps to confirm what land Council considers falls into the hazardous/high risk criteria in the Codes SEPP for excluding complying development. As discussed with Council officers, it is considered that all land in medium and high FRPs would likely fall into the Codes SEPP hazardous/high risk criteria in the study area. However, it would be desirable to reach an LGA wide position on this issue to provide a simple and consistent message to the community and certifiers.

This would be best done with a review of the existing information in Flood studies and FRMS&Ps for other areas in the LGA to confirm which areas should be considered to fall into these criteria. This review should consider for example the potential for small low or high flood islands in the low FRP that might require special considerations. The outcome of this review should be considered and endorsed by Council FRM committee and if necessary Council to reflect the FRM process. Subject to that review, a notation could be included on the Shire Flood Planning Maps for the information of certifiers and the community in general. This should be promoted with a communications strategy (example an information sheet for certifiers).

Traditionally the area to which flood planning controls applied were narrowed to a part of the floodplain now referred to as the FPA. The extent of an FPA can vary depending on the choice of a single FPL, but in NSW has typically been the extent of land defined by the 100 year flood plus 0.5 freeboard. However, current best practice requires the application of a risk based approach that in the case of FRM necessitates the application of multiple FPLs that can respond differently to the vulnerability of different land uses and variable flood hazards.

The matrix approach has been adopted in the DCP consistent with the recommendations of the Georges River FRMS&P (Bewsher 2004) and is consistent with a risk based approach. This approach does not rely on a singular FPL and therefore an FPA map is superfluous. The matrix approach operates in conjunction with the mapping of areas of like FRM issues – ie low medium and high precincts. The recent changes to the LEP and 2021 Guideline allows for Council to nominate in the DCP, an FPL or multiple FPLs and consequently the applicable FPA or FPAs. The recommended approach is to define the FPL, and therefore FPA to encompass all land within the PMF. This would be consistent with the combined extent of area mapped as within the low, medium and high precincts and the definition of flood prone land in the FDM.

This will need to be carefully communicated to explain that for any particular land use the extent of the floodplain is that which is relevant for the purposes of applying the DCP controls. For example, for residential development in the Low FRP, the application of clause 5.21 of the SLEP is only relevant to requiring residential development achieves a minimum floor level equal to the 100 year flood plus freeboard. In this way the same floor level standard is applied to sites below and marginally above the 100 year flood extent. Additionally this would allow for consideration of emergency management issues for residential development in the low FRP, where this may be warranted because of particular flood risks identified during DA assessment. The approach should not be seen as an attempt to restrict all development within the floodplain.

The use of precincts (described as FRPs in the DCP) is still considered the best approach to provide a flood map that meets all the objectives of statutory flood planning maps as discussed earlier. While it provides more complexity than a map that identifies a single FPA, it provides a format to more flexibly tailor planning controls for different land uses and flood hazard conditions consistent with a risk management approach. Further, any added complexity is offset by removing the need to rely on three other alternate map sets and the benefit of comprehensively and consistently communicating flood risk to the community.

Note that the mapping flood precincts is different to the mapping of FPCCs. The mapping of flood precinct is to identify approval pathways and matters that would need to be considered in the assessment of an application for statutory planning purposes. FPCCs map a range of flood hazard characteristics for floods of different frequency to provide a comprehensive basis informing the preparation of strategies and plans for strategic planning purposes. FPCCs maps are not limited by the concept of an FPA.

Ideally the Council Flood Maps should ultimately be accessible via the NSW Planning Portal. This would be consistent with the planning outcomes envisaged by S2.25 and Schedule 3 of the EP&A Act relating to online planning information. This would be similar to the manner by which Bushfire Prone Maps can be accessed.

Consideration was given to an option to create a separate flood precinct that grouped the high, medium and low flood precincts subject to only overland flow flooding into a single separate precinct for the purposes of applying planning controls. The purpose of this would be to differentiate controls for riverine flooding from only overland flow flooding and provide one set of DCP controls for development in this precinct. However, in discussion with Council this option has not been pursued for the purposes of this FRMS&P on the basis of Council's concern that this may not allow sufficient granularity required in the assessment of some DAs.

5.5.3 Flood Control Lot Mapping

There is no specific requirement to prepare a Flood Control Lot Map (ie that depicts flood control lots as defined by the Codes SEPP). However, in practice this is normally done for the purpose of having a GIS based source to automatically trigger which properties should be noted as a Flood Control Lot on a S10.7 Planning Certificate. Other flood maps cannot perform this function because it is common practice to exclude the "tagging" of Flood Control Lots if an immaterial proportion of the lot is affected by flooding (less than 10% being a criterion commonly used).

Flood Control Lot Maps have been used by some Councils within planning instruments. Prior to the changes brought by the Flood Prone Land Package, a few LEPs (e.g. Rockdale and Marrickville LEPs) and the DCPs of some other Councils adopted Flood Control Maps as Flood Planning Area maps. However, this is not favoured for the following reasons:

- some lots remain only partially affected by actual flooding but are tainted as wholly flood affected. This is a particular issue with large lots.
- such maps portray are distorted view of the flood risk across an area, which works against communicating clear and accurate information about flood risk to the community
- this type of map could not be used to implement the DCP controls and would therefore exist as an additional map, that would have role that is confusing to the general public.

Accordingly, it is recommended that a Flood Control Map be prepared for the purposes of tagging properties for notification on S10.7 Planning Certificates, but that such a map be contained on Council's GIS system for internal use only and not for direct public distribution.

5.5.4 LEP provisions

As discussed previously, the SSLEP previously contained a Flood Planning clause (clause 6.3) that provided heads of consideration for DAs within a FPA defined as the 100 year flood extend plus 0.5m freeboard. These heads of consideration support the more detailed controls provided by the DCP, that applied controls based on FRP mapping across the whole of the floodplain (ie up to the PMF).

As a consequence of the recent amendments to the LEP, the mandatory flood clause 5.21 now applies and Council is to separately define FPL(s)/FPA(s) to determine the area to which it applies. The 2021 Guideline recommends FPL(s)/FPA(s) be defined within a DCP.

Clause 5.22 Special flood considerations (**SFC Clause**) has also been inserted into the Standard Instrument LEP and all Councils have been asked to nominate whether they wish to opt into having this clause apply and the justification relevant to their LGA. The SFC is:

(1) The objectives of this clause are as follows—

(a) to enable the safe occupation and evacuation of people subject to flooding,

(b) to ensure development on land is compatible with the land's flood behaviour in the event of a flood,

(c) to avoid adverse or cumulative impacts on flood behaviour,

(d) to protect the operational capacity of emergency response facilities and critical infrastructure during flood events,

(e) to avoid adverse effects of hazardous development on the environment during flood events.

(2) This clause applies to—

(a) for sensitive and hazardous development—land between the flood planning area and the probable maximum flood, and

(b) for development that is not sensitive and hazardous development—land the consent authority considers to be land that, in the event of a flood, may—

(i) cause a particular risk to life, and

(ii) require the evacuation of people or other safety considerations.

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development—

(a) will not affect the safe occupation and efficient evacuation of people in the event of a flood, and

(b) incorporates appropriate measures to manage risk to life in the event of a flood, and

(c) will not adversely affect the environment in the event of a flood.

The SFC clause allows Council to define "sensitive and hazardous development" as inclusive of only any of the following purposes:

(a) boarding houses,

(b) caravan parks,

(c) correctional centres,

(d) early education and care facilities,

(e) eco-tourist facilities,

(f) educational establishments,

(g) emergency services facilities,

(h) group homes,

(i) hazardous industries,

(j) hazardous storage establishments,

(k) hospitals,

(l) hostels,

(m) information and education facilities,

(n) respite day care centres,

(o) seniors housing,

(p) sewerage systems,

(q) tourist and visitor accommodation,

(r) water supply systems.

The mandatory clause 5.21 applies to all development on land within the FPA nominated by Council and includes the following similar matters that a determining authority must be satisfied about before granting consent to a DA"

(2) Development consent must not be granted to development on land the consent authority considers to be within the flood planning area unless the consent authority is satisfied the development—

(c) will not adversely affect the safe occupation and efficient evacuation of people or exceed the capacity of existing evacuation routes for the surrounding area in the event of a flood, and

(d) incorporates appropriate measures to manage risk to life in the event of a flood, and

(e) will not adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.

As discussed above, the recommended approach is to define the FPL, and therefore FPA to encompass all land within the PMF. This should be undertaken by inserting definitions in the DCP as discussed below.

In the event that Council defines all land within the PMF extent as the FPA, the only materially different consideration required by the 2 clauses would be that subclause 5.22(2) of the SFC clause would require Council to consider emergency management issues for development that was not "sensitive and hazardous development" on land outside of the PMF extent. For example a Council could be concerned that residential development outside of a floodplain could constrain the capacity of an evacuation route required during a flood.

It is understood that the DPIE is proposing to consider the position of Councils and provide a batched insertion of the SFC Clause into LEPs in 2022. Sutherland Council has advised the DPIE that they wish to opt into inclusion of SFC Clause, primarily due to emergency management issues associated with flood prone land along the Woronora River (which is outside of the study area of this FRMS&P).

The necessity for opting into the SFC clause is beyond the scope of this FRMS&P. However Council should consider this in conjunction with the above recommendation for defining the FPA.

5.5.5 DCP Provisions

As discussed previously, the existing DCP provisions relevant to FRM have been reviewed. **Appendix C** provides comments to inform the recommendations for the FRMS&P.

Chapter 40 of the Sutherland DCP adopts a 'planning matrix approach' to identify different categories of development and their suitability within different flood risk areas and provides a tabulated presentation of planning controls that apply to the different land uses in different parts of the floodplain. Our review has concluded that in principle this approach should be retained subject to refinements. The rationale and details of these refinements are provided in Appendix C

As a consequence of the new mandatory LEP clause 5.21, definitions should be inserted into the DCP that describe the FPL as the level of the PMF without freeboard and consequently the FPA as the mapped extent of the PMF. It should be explained that no freeboard is required for the purposes of this definition given the PMF is a major flood that represents the largest probable extent of the floodplain and that this would be consistent with Council's flood risk mapping using in the application of DCP controls since before 2015. Importantly it is recognised that the definition of the FPL/FPA in this way could be misinterpreted by the community, particularly the development industry, as an intention to restrict development, and should be accompanied by a clear communications strategy to dispel any negative reaction.

While not a requirement of the brief, **Appendix E** provides a preliminary draft revised planning matrix that reflects the recommended changes to the DCP. This will require further consideration and refinement by Council (including the incorporation of principles and a technical specification as discussed below), together with amendments with the wording of the DCP provisions before commencing the DCP amendment process.

Pertinent recommended changes to the DCP are summarised below:

- Remove flood mapping from the DCP and refer to the on-line Flood Planning Shire Maps once these maps have been augmented as recommended above.

- Differentiate controls for overland flow and riverine flooding where appropriate. This would be subject to flood engineering assessment and could for example include a reduced freeboard of 0.3m for reasons such as typically lower depths of overland flow flooding compared to riverine flooding.

- At present the DCP identifies "unsuitable land [uses]" within different FRPs. There is the potential for this to be misunderstood as prohibiting development, which is not intended. Prohibitions can only be set by an environmental planning instrument such as an LEP. An LEP would prevail over a DCP where there is an inconsistency. The intention of the DCP is to identify where the risk to different land uses are likely to be difficult to overcome and the extent of potential mitigation measures needed could themselves have unacceptable environmental and amenity impacts. Also the matrix is not clear about what controls to impose if an unsuitable land use proves to be acceptable on a performance basis, To resolve these issues we recommend changes to the way unsuitable land uses are presented in the planning matrix and the incorporation of appropriate controls. Experience has shown that such uses can sometimes be acceptable with mitigation measures.

As required by the brief we have considered the option of providing FRM principles and/or guidance notes to supplement the DCP controls. The types of flood related development principles identified by Council staff for consideration include:

- Hierarchy of spatial control in managing risk: Optimising development layout to apportion flood risk in descending order: driveways, communal open space, private open space, buildings

- Hierarchy of temporal control in managing risk: Flood risk is most effectively managed when addressed as early as possible in the development process, that is, in the following order: lot subdivision, lot consolidation, building construction, building alteration and change of use
- Development proportional to flood risk: The greater the flood risk the greater the need to avoid development of the undeveloped part of the property subject to that risk
- Redevelopment: Only allowed where risk is at best reduced, or at worst not increased now or in the future.
- Vulnerability: Vulnerable development to be subject to a greater level of control
- Intensification: Should not be supported if exposing more people or property to flood risk but encouraged where flood risk can be reduced
- Flood awareness: Residents, workers and visitors / customers have different vulnerabilities and levels of awareness, and must be managed differently
- Structural flood modification measures: Can be used to protect development where the building is retained (subject to flood effects control) but not where a new building is proposed
- Indirect damages: Health and emotional impacts of flooding are to be considered, particularly flow under buildings, frequency of inundation, clean-up costs, etc
- Concessional development: Minor, non-consecutive modifications can be made to a building without fully satisfying flood-related development controls, but only to the point that the cumulative increase in flood risk is not significant.
- Time-limited development: We may support an increase in flood risk for a time-limited development consent if the original consent to which the property would revert to following the end of the time-limited consent, is modified to enable flood-related development controls to be imposed following temporary development

Care is required to ensure further principles and/or guidance notes do not have the converse effect of creating greater complexity for Council DA assessment officers and for applicants by having additional documentation to consider. Based on our discussions with Council staff, the primary issues facing assessment planners is where the occasional lack of existing flood mapping data results in FRM not being identified until after the lodgement of a DA. Where technical FRM issues arise in the DA assessment process these are dealt with by Council engineers who have identified the need to document technical matters relevant to the assessment of flood impacts and design of mitigation measures. Consequently, we consider that the following could be undertaken:

- appropriate principles can either be included within the objectives to the controls or as performance criteria
- guidance notes, that would relate to matters of a technical nature most relevant to detail engineering considerations, could be incorporated into an Environmental Specification.

DCP controls can typically comprise of objectives, performance criteria and prescriptive controls. Stating of performance criteria alongside of prescriptive controls can assist in understanding the controls and to provide a basis to assess when variations to the prescriptive control should be supported. The necessity to apply a flexible performance based approach to the application of DCP controls is a requirement of s.4.15(3A)(b) of the EP&A Act. The intent of the above principles are in some cases implicit in the prescriptive controls or not directly relevant as it would not assist in the assessment of a DA. However, the majority of the principles can appropriately be incorporated into the DCP as objectives or performance criteria.

Council Currently publishes Environmental Specifications which are essentially matters of technical policy that may be referred to in conditions of consent or controls within the DCP. Specifications are not intended to contain controls that influence the design process but include matters of technical compliance. This includes a Stormwater Management Specification. The nature of the guidance notes identified in the brief relate to technical matters beyond the scope of this report. However, in principle we consider that they could be incorporated into a revised and expanded Stormwater Specification that includes FRM matters or form part of a new independent FRM specification.

The DCP changes should also incorporate provisions to deal with climate change related flood risk. This would be relevant to the principle regarding time-limited development consents and this is addressed in the following section of this report.

If further, guidance is required by Council DA assessment officers, this might best be provided by way of in-house training.

5.5.6 Climate Change

The consideration of climate change effects requires determining what would be reasonable standards to apply today to ensure that a development has an acceptable level of flood immunity in the future based on projected climate change flood effects. The aim should be to take a precautionary approach to contain flood risks at those levels otherwise considered acceptable today where this can be practically achieved. The time period for consideration of the future is typically years 2050 and 2100, based on 50 year and 100 year international forecasts for sea level rise provided from a year 2000 base.

The 2010 NSW Sea Level Rise Policy recommends that strategic and statutory planning documents could respond by restricting the intensification of development in areas subject to predicted climate change flood risk or applying planning controls to manage the additional risk. The mechanisms that might be applied include:

- adopting climate change design flood levels when assessing the suitability of land at the strategic planning stage and assessing potential development outcomes associated with planning proposals
- increasing the design flood levels in current planning controls that apply to development to take into account predicted climate change effects. This would typically be practical in greenfield developments but often impractical for developments within established areas
- imposing time-limited consents to provide the potential to remove, replace or adapt development in the future.

The first mechanism is basically only relevant at a high level strategic planning stage when delineating the footprint of future urban land in a greenfield situation, which is mostly irrelevant to the Sutherland LGA.

In regard to both the first and second mechanisms, a sensitivity analysis is appropriate. This analysis should be based on the FRM considerations provided in Table 6 for strategic planning purposes, particularly to assess the acceptability of flood risks associated with a Planning Proposal that would provide for significant new development.

Variable FPLs for different land uses and scale of development can be used where this would allow for a more practical planning outcome. This would involve taking into consideration the vulnerability of different development, the expected life of development and the practicality of developing at higher levels. More vulnerable land uses and/or those with an expected longer life span should be assigned climate change flood levels. Other uses could be subject to time limited consents. This can be integrated into the planning matrix approach.

In a practical sense, the adoption of the higher FPL could be appropriate for new areas or major developments where additional filling or higher floor levels can be readily achieved with marginal additional cost and minimal impacts on surrounding development. Conversely it could be difficult to implement higher FPLs for minor development within established areas where there could be amenity, streetscape or drainage impacts.

In regard to the third mechanism, the Court has been reluctant to accept time related consents (see for e.g. *Newton and anor v Great Lakes Council [2013] NSWLEC 1248*). However, if to be considered for inclusion in a future DCP, it should be accompanied with clear objectives and criteria for how it would be applied, what happens at the expiration of the consent period, and opportunities to extend the consent period if circumstances change. The expiration date should also be event triggered (e.g. the reaching of a certain mean sea level) as opposed to calendar date triggered.

The types of development subjected to time limited consents should be determined based on one or more of the following criteria:

- where climate change flood risk is unlikely to remain acceptable post 2050 (e.g. because the land would become subject to regular tidal inundation or flood risks are projected to become unacceptable)

- the development is a low capital investment relative to the likely financial capacity of proponent (e.g. residential outbuildings, or basic industrial/warehouse buildings)

- the type of building form and use is commonly redeveloped in a 40 year period (e.g. indoor recreation facilities);

- the typical site context means redevelopment in 2050 is unlikely to affect surrounding development (e.g. large lot residential)

- likely future changes in technology or resource availability could warrant redevelopment in approximately 40 years (e.g. car parking and automotive related uses).

Council's current practice is to consider the effect of climate change induced sea level predictions on flooding when setting FPLs for floor levels. The imposition of minimum floor levels to take into account the longer term effects of climate change might not always be practical. Further, while this provides added protection for the habitable floor levels of buildings it does not address other issues such as the inundation of the remainder of the property or of roads and other public spaces. Such matters would need to be resolved as part of an adaptation strategy which is beyond the scope of this FRMS&P.

5.6 Notifications (communication)

While planning documents are not the principal means to advise people of flood risks for the purposes of creating a flood aware and prepared community, they nonetheless form a component of information sources. To ensure that council exercises an appropriate duty of care of responsibly informing the public of flood risks, and to avoid undermining floor awareness education campaigns, it is important to ensure a consistent message is provided by:

- the FRMS&P
- general planning studies and strategies
- Council's on-line mapping system
- definitions, mapping and controls within planning policies (i.e. LEP and DCP); and
- S10.7 (formerly) S149 Planning Certificates

Continuing with the planning matrix approach discussed above, provides a sound basis to ensure the appropriate communication of flood risk within the planning system. Ideally, the S10.7 certificate notations should be standardised for all sites across the LGA. These should be undertaken in conjunction with the recommendations for upgrading the DCP controls and flood maps.

The information regarding flood risk provided with a Section 10.7 Certificate, would not in itself lead to any alteration to the permissibility of development but is more directed towards providing factual information (important due to liability issues as well as FRM outcomes) to increase awareness of the potential flood risks known to Council and to provide full and consistent messaging about flood risks. While, the detail content of a Section 10.7 Certificate is constrained by that specified by the EP&A Regulations, the application of the planning matrix approach and recommended flood planning maps provides a singular comprehensive source of flood risk information that provides a balance between statutory compliance and comprehensive disclosure.

A "Flood Information Sheet" that provides pro-forma based data that references the DCP, the range of flood levels[20] for different key flood events to determine minimum levels for habitable floors and garages/driveway access, and existing floor levels (where known) for an individual site can be purchased at a fee from Council. A Flood Information Sheet is currently independent to a Section 10.7 Certificate.

[20] A range of flood levels is provided as these flood levels will typically vary across a site due to the hydraulic gradient of flood waters and changes in site levels.

Having regard to the 2021 Planning Guideline, the information provided with a Flood Information Sheet, would ideally be included with Section 10.7(5) certificate to discharge Council's responsibility to provide any additional information regarding flooding not covered by a Section 10.7(2) certificate.

Council could also consider providing Flood Information Certificates with all Section 10.7(2) certificates as means of improving flood awareness. Note, this would be included as advisory information that did not formally form part of the certificate.

Additionally, our investigations indicated that Flood Information Sheets may give the false impression that this outlines all the information that a proponent may need to prepare for a DA and there is often a misunderstanding of the flood information and how it is applied. This would be particularly relevant if required to satisfy Section 10.7(5) of the EP&A Act. Consequently, we recommend that the standard content of the flood information sheet be expanded to include:

- an explanation of the source of the flood information, what additional information might be available including any relevant Flood study, FRMS and FRMP, and the full extent of information that might be required to fully understand the flood risk on the site and to inform the preparation of a development application

- the FRM information that Council could require to submitted with a DA

- the FRM factors that Council could take into consideration when assessing a DA

- the residual flood risks that could affect a site despite satisfying Council's DA requirements

- provide an email link to provide feedback on the flood information sheet and how it could be improved.

Having regard to previous discussion and recommendations in this report, the following principles should be applied in the drafting of S10.7(2) Certificates.

- where flood risk precinct (FRP) mapping has been undertaken the applicable FRP should be noted, with an explanation as to its meaning and application under the DCP provisions

- for the purposes of both Clauses 7A(1) and 7A(2) of Schedule 4 to the Regulations, all land mapped within an FRP, or Initial Assessment Area, would be within the FPA, which is inclusive of land up to the PMF

- all properties tagged on the flood control map prepared for internal Council use, would also be noted as "flood control lots" for the purposes of the Codes SEPP

- where Council is unsure of whether a property contains flood liable land (which would normally be mapped as "Initial Assessment") a general notation to this effect can be placed with an explanation that a flood study could identify that the land is subject to flooding, in which case flood related controls could apply.

Many people only purchase a Section 10.7(2) certificate and not the 10.7(5) certificate which can provide more information. Advice should be provided on the Section 10.7(2) certificate that more detailed flood information is available and consideration should be given to purchasing a Section 10.7(5) Certificate or Flood Information Sheet. Council should also consider providing Flood Information Sheets as a standard part of a Section 10.7(5) certificate.

Appropriate wording for the notifications should be determined based on legal advice. This should occur concurrently with the adoption of the new LEP and FRM DCP provisions.

5.7 Incentive Program for Flood Smart Fencing

Council could prepare a shortlist of acceptable fence designs that minimise their impact on flood behaviour. This guidance could ether include technical requirements which specify performance outcomes or provide a shortlist of designs to choose from.

An example of a technical guidance note could include:

- a percentage range for the open area of the fence (say 50-75%) between the existing ground level and the flood planning level
- specifications for openings could also be specified, for example, for all openings to be at least 75mm wide to allow the flow of water.

While this is a simpler option, Council may prefer a shortlist of specific fence designs to better understand their construction and maintenance cost, especially where they might be paying for or reimbursing a landowner, as discussed later. Possible design solutions include:

- fences with an integrated louvre design along the bottom of the fence between ground level and the FPL, that would open under the pressure from overland flows
- fixed mesh element along the bottom to allow water to pass through the fence but still allow a solid upper portion to be provided for privacy. The mesh component would need to be sized to ensure pets cannot pass through gaps while also avoiding material or debris to be caught.
- Timber paling fencing with alternating vertical slats that provide gaps to allow floodwater to pass through (Error! Reference source not found.).

Figure 11: Example of a timber paling flood fence

A third option is to outline possible modifications to existing fences instead of replacing a fence along an entire boundary.

These options could be promoted as part of a voluntary fence program for flood control lots. We are not aware of any similar existing programs but recommend that the parameters of such a program consider:

- Using flood study data to generally determine parts of the floodplain where modified fences would be beneficial.
- A promotional campaign that highlights the approval requirements for fencing on flood control lots, together with Council's voluntary subsidy program for flood smart fencing and the benefits to the community.
- Eligibility be subject to an initial appraisal by a Council flood engineer which has regard to the location of the fence relative to flood flow paths, the condition of the existing fence and the potential impact of improving flows in situations where the retarding of flows has been an historical occurrence.
- A full or partial subsidy be provided in regard to the design plans, preparation and lodgement of an application (if needed), the demolition and removal of the existing fence and the construction of the new fence. The subsidies could be provided as either the direct meeting of costs at the fence construction stage or a full or incremental offset against payable Council rates.
- The program not being available where the requirement for a new fence is imposed as condition of a DA or is likely to be imposed as condition of a pending DA.
- Where flood smart fencing is constructed Council will place a covenant of the affected properties to ensue such fencing is retained in perpetuity.

In addition to financial subsidies, Council could adjust approval pathways to encourage the use of a Flood Smart Fencing Program. At present, no fences on flood control lots are technically exempt development under the Codes SEPP. Also, no relevant exempt development provisions exist in SSLEP. However, in accordance with clause 1.9(9) of the Codes SEPP, if the SSLEP provided for exempt development, then the SSLEP would prevail.

Accordingly, Council could amend Schedule 2 of SSLEP to include fencing within all residential, business and industrial zones on a flood control lot that is approved as part of Council's Flood Smart Fencing Program as exempt development. The amendment to schedule 2 would also need to specify all criteria to be satisfied by such fences (i.e. height, materials and design for front side and rear boundaries) including flood related specifications. Where any of these criteria are not satisfied a full DA would need to be submitted. The program would need to first established so that it can be defined in the LEP. This would provide a mechanism to both encourage the construction of flood smart fencing and reduce the administrative burden of needing to process a development application for all fencing on flood control lots.

Implementation details would need to be determined after acceptance of the program as part of the FRMS&P. To manage construction and maintenance costs, Council could prepare and cost standard fence designs. If a landowner seeks to construct a fence that exceeds a standard fence design preferred by Council, a contribution cold be paid only up to the value of what would have been paid by Council for a standard fence design. Where a fence would be constructed partly or in full by Council an implementation option could include requiring a landowner to provide an adequate number or quotations. Alternatively, Council could engage a shortlist of contractors to construct a fence.

5.8 Summary of Issues, Options and Recommendations

The following provides a summary of existing issues identified during the course of preparing this study and recommendations for implementation as part of the FRMS&P. These recommendations are both specific to the Woolooware study area and necessarily generally applicable to the FRM planning framework applicable to the whole LGA.

Issues	Recommendations
Definition of Flood Planning Levels: • 0.5m freeboard is appropriate for riverine flooding but is typically excessive for overland flow flooding. • 2021 Flood Planning Guideline requires Councils to define FPL(s) and FPA(s) preferably in a DCP. • The adoption of a singular FPL in the LEP contradicts the best practice approach to risk management approach of applying multiple FPLs	**SLEP 2015** 1. Consider defining the FPL/FPA for the purposes of specifying the area to which clause 5.21 applies as the extent of the floodplain (ie up to the PMF) within the DCP as discussed below 2. Having regard to the above recommendation review the necessity for opting into the application of clause 5.2 Special Flood Considerations. 3. When undertaking a review of the LEP or FRMS&Ps that capture the Georges River, Woronora River and those areas of Port Hacking that are not part of the coastal zone, consider whether the foreshore building line imposed via clause 6.10 of the LEP should be adjusted to include all lands identified to be within a high flood risk precinct.

Issues	Recommendations
to different land uses and components of development. • Mapping of the FPA based on a single FPL that is below the PMF	
Mapping of Flood Planning Areas	
Adequacy of flood Planning Clause	
Appropriateness of zonings within Study Area	
Requires an approach that can encapsulate riverine and overland flooding.	**SDCP 2015** 4. Review the flood risk management provisions of Chapter 40 of the DCP to incorporate controls for overland flow flooding and to otherwise remove superfluous content and simplify and clarify existing provisions generally in the manner set out in **Appendix C**.
Require an approach that can be readily applied to identify Flood Control Lots for the purposes of the Codes SEPP and prescribed notifications for S10.7 Certificates.	5. Revise the flood planning matrix in the DCP to incorporate discrete controls for overland flow flooding and to rationalise and simplify existing controls generally in the manner set out in **Appendix E**. This should include the refinement of recommended performance criteria to incorporate relevant flood related development principles.
Providing Guidance for Determining application of exempt and complying development options	6. Expand upon the objectives of controls to incorporate relevant flood related development principles where not appropriately included within performance criteria.
How to address situations where flood risks have not been confidently fully mapped (presently identified and mapped as "Initial Assessment Potential Flood Risk".	7. Consider incorporating existing and any required additional technical engineering guidance into an Environmental Specification. This could be incorporate into a revised and expanded Stormwater Specification that includes FRM matters or form part of a new independent flood risk management specification.
Review potential cumulative impact of currently permitted development through all approval pathways (DA, Exempt, Complying, without consent and State Significant Development).	8. Define the flood planning level and flood planning area for the purposes of clause 5.21 of the LEP as the extent of the floodplain as defined by the Floodplain Development Manual (ie up to the PMF). This should be accompanied by a clear communications strategy to explain that these definitions provide consistency with the flood information known to Council and already made publicly available on flood risk precinct maps and allows for consistency between the

Issues	Recommendations
	application of the LEP and DCP controls which rely on these maps. 9. Review the freeboard for overland flow flooding having regard to hydraulic engineering considerations. 10. Provide further guidance in An Environmental Specification to address the design criteria to be satisfied for subfloor flow paths. 11. Remove flood mapping from the DCP and refer to the on-line Flood Planning Shire Maps once these maps have been augmented as recommended below. **Flood Planning Maps** 12. The DCP Flood Risk Management Maps be removed and the on-line Flood Planning Shire Maps be augmented to provide the sole source of information for statutory planning purposes. 13. Maintain the Shire Flood Planning Maps as the primary source of flood maps used for statutory planning purposes, and continually update that as additional and revised information is available. These maps should continue to show the extent of land within low, medium and high flood risk precincts for both riverine and overland flow flooding and also differentiate between areas subject to riverine and only overland flow flooding. 14. A Flood Control Map be prepared for the purposes of tagging properties for notification on S10.7 Planning Certificates, but that such a map be contained on Council's GIS system for internal use only and not for direct public distribution. 15. Undertake a review of existing flood studies and FRMS&Ps to confirm whether all medium and high FRPs in the LGA should be considered by Council to be land that does not meet the hazardous/high risk criteria in the Codes SEPP for complying development. Subject to that review, include a notation on the Shire Flood Planning Maps for the information of certifiers and promote this with a communications strategy. 16. For strategic planning purposes, use the flood planning constraint categorisation approach outlined by Guideline 7-5 Flood Information to Support Land-use Planning[21] with further guidance notes that are provided by **Table 5**.

[21] This is a supporting document for Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (Australian Institute of Disaster Resilience – AIDR, 2017

Issues	Recommendations
An approach to address climate change in both the strategic and DA assessment processes is required.	**Climate Change** 17. Adopt climate change design flood levels when assessing the suitability of land at the strategic planning stage and assessing potential development outcomes associated with planning proposals. 18. Undertake a sensitivity analysis to determine whether to increase the design flood levels in current planning controls that apply to development to take into account long term predicted climate change effects. Variable FPLs for different land uses and scale of development can be used where this would allow for a more practical planning outcome. 19. Review the appropriateness of introducing a policy (within the DCP) of imposing time-limited consents to provide the potential to remove, replace or adapt development in the future. The policy should apply an expiration date that is event triggered (e.g. the reaching of a certain mean sea level) as opposed to calendar date triggered. The types of development subjected to time limited consents should be determined based on one or more of the following criteria: • where climate change flood risk is unlikely to remain acceptable post 2050 (e.g. because the land would become subject to regular tidal inundation or flood risks are projected to become unacceptable) • the development is a low capital investment relative to the likely financial capacity of proponent (e.g. residential outbuildings, or basic industrial/warehouse buildings) • the type of building form and use is commonly redeveloped in a 40 year period (e.g. indoor recreation facilities); • the typical site context means redevelopment in 2050 is unlikely to affect surrounding development (e.g. large lot residential) • likely future changes in technology or resource availability could warrant redevelopment in approximately 40 years (e.g. car parking and automotive related uses).
Notifications about flood risk can be confusing to the general public and unhelpful in achieving FRM outcomes.	**Notifications** 20. The standard content of the flood information sheet be expanded to include: • an explanation of the source of the flood information, what additional information might be

Issues	Recommendations
	available and the full extent of information that might be required to fully understand the flood risk on the site and to inform the preparation of a development application • the FRM information that Council could require to submitted with a DA • the FRM factors that Council could take into consideration when assessing a DA • the residual flood risks that could affect a site despite satisfying Council's DA requirements, and • provide an email link to provide feedback on the flood information sheet and how it could be improved. All final wording changes to the notifications should be based on legal advice. 21. That the wording of Section 10.7(2) Planning Certificates be reviewed to ensure consistency with the following principles: • where flood risk precinct (FRP) mapping has been undertaken the applicable FRP should be noted, with an explanation as to its meaning and application under the DCP provisions • for the purposes of both Clauses 7A(1) and 7A(2) of Schedule 4 to the Regulations, all land mapped within an FRP, or Initial Assessment Area, would be within the FPA, which is inclusive of land up to the PMF • all properties tagged on the flood control map prepared for internal Council use, would also be noted as "flood control lots" for the purposes of the Codes SEPP • where Council is unsure of whether a property contains flood liable land (which would normally be mapped as "initial Assessment") a general notation to this effect can be placed with an explanation that a flood study could identify that the land is subject to flooding, in which case flood related controls could apply 22. That Council consider providing flood information sheets as part of a Section 10.7(5) certificate and including it with Section 10.7(2) Certificates or combining the Section 10.7(2) and (5) Certificates in the one purchase.
Fencing is erected with minimal control but can have significant impacts of flood behaviour. Flood Smart Fencing Initiatives would be desirable.	**Flood Smart Fencing** 23. Raise awareness of the need for development approval for fencing on flood control lots as part of broader community flood awareness program, within the DCP and as part of any potential voluntary fence modification program.

Issues	Recommendations
	24. That Council investigate the feasibility of implementing a flood smart fencing program involving a promotional campaign, establishing eligibility criteria, determining the extent of subsidies to be offered and implementation details. 25. Subject to the implementation of a flood smart fencing program, Council amend Schedule 2 of SSLEP to include fencing within all residential, business and industrial zones on a flood control lot that is approved as part of Council Flood Smart Fencing Program as exempt development. The amendment to Schedule 2 would also need to specify all criteria to be satisfied by such fences (i.e. height, materials and design for front side and rear boundaries).
Flow Paths and be inadvertently blocked causing detrimental impacts on flood behaviour. Policy direction on the imposition of easements to recognise flood flow paths would be desirable.	**Flow Paths and Drainage Easements** 26. Where historically a piped drainage system has been installed but no easement had been created for the pipeline or overland flow path (if needed) then Council should use its best endeavours to create an easement. Council should preferentially seek to negotiate the dedication of such easements without compensation when opportunities present (such as when considering a planning proposal or development application). In problematic areas where flow paths may be blocked and potentially cause significant flood impacts, Council could consider attempting to acquire the easement by way of a negotiated settlement.

6 Conclusion

This report has been prepared to review the planning considerations relevant to the FRMS&P being prepared for the Woolooware catchment. This catchment is mostly affected by overland flow flooding.

The 2004 Georges River FRMS&P provided the basis for Council's current FRM planning controls. These were developed 15 years ago and are due for updating. They were also prepared for a specific riverine flooding context and not overland flow flooding. This report has provided the opportunity to review existing planning controls and FRM planning related policies and to incorporate consideration of overland flow flooding.

To provide a meaningful review it was important to review the planning polices and controls as they apply to the whole LGA and consider how overland flow flooding can be addressed in conjunction with riverine flooding.

The review outlined within this report has provided recommendations regarding:

- guidance for how to consider FRM matters when undertaking strategic planning including determining the suitability of different land uses in different areas of the floodplain
- a detailed review of existing LEP and DCP development controls
- principles for consideration of climate change flood effects
- an approach to rationalise, augment and clarify and the existing various flood planning maps produced by Council
- principles to be applied to ensure the appropriate communication of flood risk through planning documents, is not misleading, including S10.7 Planning Certificates
- recommendations for flood smart fencing initiatives
- policy directions for the imposition of easements to recognise flood flow paths would be desirable.

Many of these recommendations are interdependent, with the rationalisation of flood planning mapping being pivotal to ensuring all recommendations are successfully implemented. Importantly, both planning and FRM are dynamic processes and will require on-going monitoring and review as new information and issues emerge.

7 Glossary

Abbreviation	
100 year flood	A flood that occurs on average once every 100 years. Also known as a 1% flood. See Annual Exceedance Probability (AEP) and Average Recurrence Interval (ARI).
Annual Exceedance Probability (AEP)	AEP (measured as a percentage) is a term used to describe flood size. It is a means of describing how likely a flood is to occur in a given year. For example, a 1% AEP flood is a flood that has a 1% chance of occurring, or being exceeded, in any one year. It is also referred to as the '100 year flood' or 1 in 100 year flood'. The terms 100 year flood, 50 year flood, 20 year flood etc., have been used in this study. See also Average Recurrence Interval (ARI).
Australian Height Datum (AHD)	A common national plane of level approximately equivalent to the height above sea level. All flood levels, floor levels and ground levels in this study have been provided in metres AHD.
Average Recurrence Interval (ARI)	ARI (measured in years) is a term used to describe flood size. It is the long-term average number of years between floods of a certain magnitude. For example, a 100 year ARI flood is a flood that occurs or is exceeded on average once every 100 years. See also Annual Exceedance Probability (AEP).
BCA	Building Code of Australia is a uniform set of technical provisions for the design and construction of buildings and other structures throughout Australia. The BCA is produced and maintained by the Australian Building Codes Board (ABCB), and given legal effect through the Building Act 1975.
CDC	Complying Development Certificate
Council	Sutherland Shire Council
DA	Development Application
DCP	Development Control Plan
DPIE	The NSW Department of Planning Industry and Environment (formerly NSW Department of Planning and Environment – DPE, Department of Planning and Infrastructure – DPI and Department of Planning – DoP).
DA	Development Application
Development Control Plan (DCP)	A DCP is a plan prepared in accordance with the Environmental Planning and Assessment Act, 1979 that provides detailed guidelines for the assessment of development applications.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
EP&A Act	Environmental Planning and Assessment Act, 1979
EPA Regulation	Environmental Planning and Assessment Regulation 2000
flood	A relatively high stream flow that overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal

Abbreviation	
	inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood hazard	The potential for damage to property or risk to persons during a flood. Flood hazard is a key tool used to determine flood severity and is used for assessing the suitability of future types of land use.
flood level	The height of the flood described either as a depth of water above a particular location (e.g. 1m above a floor, yard or road) or as a depth of water related to a standard level such as Australian Height Datum.
flood liable land	Land susceptible to flooding up to the Probable Maximum Flood (PMF). Also called flood prone land. Note: that the term flood liable land covers the whole of the floodplain, not just that part below the Flood Planning Level.
FDM	Floodplain Development Manual
Flood Planning Levels (FPLs)	The combination of flood levels and freeboards selected for planning purposes, as determined in Floodplain Management Studies and incorporated in Floodplain Management Plans. The concept of flood planning levels supersedes the designated flood or the flood standard used in earlier studies.
flood prone land	Land susceptible to flooding up to the Probable Maximum Flood (PMF). Also called flood liable land in the Floodplain Development Manual.
FRM	Flood Risk Management
Flood risk precinct	An area of land with similar flood risks and where similar development controls may be applied by a council to manage the flood risk. (The flood risk is determined based on the existing development in the precinct or assuming the precinct is developed with normal residential uses). (See also risk).
Flood Study	A study that investigates flood behaviour, including identification of flood extents, flood levels and flood velocities for a range of flood sizes.
floodplain	The area of land that is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land or flood liable land.
Floodplain Risk Management Plan (FRMP)	The outcome of a Floodplain Risk Management Study. (Note: that the term 'risk' is often dropped in common usage.
Floodplain Risk Management Study (FRMS)	Studies carried out in accordance with the Floodplain Development Manual (NSW Government, 2005) that assesses options for minimising the danger to life and property during floods. These measures, referred to as 'floodplain management measures/options', aim to achieve an equitable balance between environmental, social, economic, financial and engineering considerations. The outcome of a Floodplain Risk Management Study is a Floodplain Risk Management Plan.
floodway	Those areas of the floodplain where a significant discharge of water occurs during floods. Floodways are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
freeboard	A factor of safety expressed as the height above the Design Flood Level. Freeboard provides a factor of safety to compensate for uncertainties in the

Abbreviation	
	estimation of flood levels across the floodplain, such and wave action, localised hydraulic behaviour and impacts that are specific event related, such as levee and embankment settlement. Note: that freeboard should not be used to allow for sea level rise impacts but can be used to allow for uncertainties in estimating climate change impacts and other effects in accordance with the Floodplain Development Manual and other Government guidelines
high flood hazard	For a particular size flood, there would be a possible danger to personal safety, able-bodied adults would have difficulty wading to safety, evacuation by trucks would be difficult and there would be a potential for significant structural damage to buildings.
Local Environmental Plan (LEP)	A Local Environmental Plan is a plan prepared in accordance with the Environmental Planning and Assessment Act, 1979, that defines zones, permissible uses within those zones and specifies development standards and other special matters for consideration with regard to the use or development of land.
LGA	Local Government Area
low flood hazard	For a particular size flood, able-bodied adults would generally have little difficulty wading and trucks could be used to evacuate people and their possessions should it be necessary.
merit approach	The principles of the merit approach are embodied in the Floodplain Development Manual (NSW Government, 2005) and weigh up social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and wellbeing of the State's rivers and floodplains.
OEH	Office of Environment and Heritage (being the government agency responsible for flooding in NSW – formerly the Department of Environment, Climate Change and Water, DECCW and now part of the DPIE.
overland flow path	The path that floodwaters can follow if they leave the confines of the main flow channel, or in the upper areas of catchments, these are the paths that runoff takes on its way to pipes or watercourses such as channels, creeks and rivers. Overland flow paths can occur through private or public property including along roads. Waters travelling along overland flow paths, often referred to as 'overland flows', are usually on their way to a watercourse or pipe system, or in some cases, may be diversions from one watercourse or pipe system to another.
Probable Maximum Flood (PMF)	The largest flood likely to ever occur. The PMF defines the extent of flood prone land or flood liable land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with the PMF event are addressed in the current study.
reliable access	Reliable access during a flood means the ability for people to safely evacuate an area subject to imminent flooding to a defined regional evacuation route within effective warning time, having regard to the depth and velocity of flood waters, the suitability of the local evacuation route, and without a need to travel through areas where water depths increase.
risk	Risk is measured in terms of consequences and likelihood. In the context of floodplain management, it is the likelihood and consequences arising from the interaction of floods, communities and the environment. For example, the potential inundation of an aged person's facility presents a greater flood risk

Abbreviation	
	than the potential inundation of a sports ground amenities block (if both buildings were to experience the same type and probability of flooding). Reducing the probability of flooding reduces the risk, increasing the consequences increases risk. (See also Flood Risk Precinct).
SEPPs	State Environmental Planning Policies

APPENDIX A: EXAMPLE DAs WITH FRM ISSUES

DA	DA Scope	Matter	Response
DA-16-0314	Demolition of existing structures and construction of a residential flat building containing residential 7 units.	Mapped as flood affected in the Woolooware Bay Catchment Flood Study.	Lifted site to RL 5.5 AHD which caused non-compliances with FSR and height controls. These were subsequently supported by Cl. 4.6 variations.
DA-16-0925	Fit-out and use of an existing industrial building as a hardware and building supplies store (temporary Bunnings Store) for a maximum of 3 years including replacement signage.	Site affected by high hazard flooding. Flood impacts from intensification of use.	Conditions requiring a modification to alter the car park layout and provide a Flood Emergency Management Plan, restrictions on car parking use, preparation a Site Flood Emergency Management Plan prior to CC, and use as a hardware store limited to a maximum of 3 years.
DA-16-1253	Alterations and additions to the existing Hotel, change of use of the existing Hotel's accommodation rooms to office space, construction of outdoor play area and provision of a food truck.	The site is affected by high hazard flooding and could increase flood risk to life and property.	Install flood doors and panels to prevent inundation. Provide and enforce a Flood Emergency Response. A condition was imposed to limit the maximum number of patrons on site at any one time.
DA-16-1523	N/A	Highly flood affected with a history of flooding. Level of FIA provided not enough with unclear strategy implementation. How the 100mm in a 24 hour period has been derived is also unclear. Issue of use intensification.	N/A
DA-17-0782	Consolidation of 3 lots and construction of a residential flat building containing 34 dwellings.	Modelling and design issues in flood assessment leading to issues in the flood maps provided with the DA. Proposed relocation of Council easement. Plans showing pipes with 90 degree bends. High hazard flood classification.	Revised DRAINS modelling with a reduced concentration time for pervious and impervious surfaces and modelling of additional storm events. Preparation of post-development modelling. Adjustments to easement pipe realignment.

DA	DA Scope	Matter	Response
DA-17-1606	Alterations and additions to an existing industrial warehouse.	Site affected by the 1% AEP. A habitable area would be located in a flood affected area.	Raise the FFL to 2.8m AHD. Redesign additional concrete slab on piers and keep the under croft area open Maintain an open vertical gap between the existing and new floor.
DA-18-0198	Alterations and additions to existing Woolooware Golf Club.	Alterations located on land identified as flood affected under the 2014 Woolooware Bay Catchment Flood Study.	Prepare a flood emergency response plan. Shelter in place not supportable.
DA-18-0305	Demolition of existing structures, construction of a multi dwelling housing development containing 4 dwellings and strata subdivision.	Increased building area in flood prone land under the Woolooware Bay Catchment.	Redesign and amended architected plans to raise levels and provide a crest to the car park.
DA-18-0377	Construction of 3 townhouses and 1 villa and strata subdivision.	Rear third of the site is affected by high hazard flooding in the 1% AEP event.	Not determined at time of this report.
DA-18-0609	Demolition of existing structures and construction of a multi dwelling development with two swimming pools.	Flood affected under the 2014 Woolooware Bay Catchment Flood Study.	FIA was submitted but suggested levels that were not supported by any modelling. Amended design of ground floor and garage levels of townhouse 1 to raise levels to 6.6 and 7.1 AHD respectively. Insufficient information.
DA-18-0869	Alterations and additions to existing dwelling, demolition of two existing garages and construction of a new garage, basement gym and pool.	Proposed development could increase flood depths by up to 50mm.	Construction of a flood wall along the southern boundary.

APPENDIX B: REVIEW OF LEP PROVISIONS

LEP Clause	Sutherland LEP 2015	Comment
1.2 (2) Aims of Plan	*(d) to minimise risk to life, property and the environment from hazards, particularly bush fires, flooding and climate change,*	This aim appropriately covers a range of hazards relevant to the LEP. No changes are recommended.
5.21 Flood Planning	This is now a compulsory LEP clause and cannot be altered or removed. The clause applies to the flood planning area, defined as: *flood planning area has the same meaning as it has in the Floodplain Development Manual.* The relevance is not clear but subclauses (4) and (5) include the following note and definition: *(4) A word or expression used in this clause has the same meaning as it has in the Considering Flooding in Land Use Planning Guideline unless it is otherwise defined in this clause.* *(5) In this clause—* *Considering Flooding in Land Use Planning Guideline means the Considering Flooding in Land Use Planning Guideline published on the Department's website on 14 July 2021.*	The clause contains objectives and controls based on sound FRM principles. The 2021 Guideline provides that Council should define an FPL or FPLs (and consequently FPAs) in their DCP. The focus on a singular FPL does not meet current FRM best practice, and an alternate approach is outlined and discussed in the report. Further, while the application of a 0.5m freeboard might be appropriate for riverine flooding it is typically excessive for overland flow flooding. This consequently leads also leads to a need for multiple FPLs.
5.22 Special flood considerations (**SFC**)	Council is to opt into the inclusion of this optional SFC clause in the standard instrument. The clause applies to sensitive and hazardous development (as listed in the clause) on land between the FPA and PMF and provides additional emergency management considerations.	Council has advised that the adoption of this clause would be justifiable having regard to the flood risk issue in locations such as along the Woronora River. These issues would not be relevant to the study area. Clause 5.21(3)(c) provides similar considerations as does clause 5.22 for all land uses but only within a defined FPA. Consequently the necessity of applying clause 5.22 should be reviewed with the regard to the recommendations in this report for defining the FPA.
6.4 Stormwater Management	*(1) The objective of this clause is to minimise the impacts of urban stormwater on land to which this clause applies and*	This clause applies to most land in the LGA except land zoned for special uses (SP1, SP2 and SP3), recreation (RE1 and RE2) and environmental lands and

LEP Clause	Sutherland LEP 2015	Comment
	on adjoining properties, native bushland and receiving waters. *(2) This clause applies to all land in—* *(a) residential, business and industrial zones, and* *(b) Zone E3 Environmental Management and Zone E4 Environmental Living.* *(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development—* *(a) is designed to maximise the use of water permeable surfaces on the land having regard to the soil characteristics affecting on-site infiltration of water, and* *(b) includes, if practicable, on-site stormwater retention for use as an alternative supply to mains water, groundwater or river water, and* *(c) avoids any significant adverse impacts of stormwater runoff on adjoining properties, native bushland and receiving waters, or if that impact cannot be reasonably avoided, minimises and mitigates the impact.*	waterways (E1, E2, W1 and W2). The clause is primarily focussed on minimising stormwater runoff and maximising water re-use. However, subclause (3)(c) effectively requires an avoidance of the impacts of both the quantity and quality of stormwater runoff on adjoining properties in general and bushland and receiving waters in particular. Stormwater as referred to in this clause can be described as "local drainage" defined as "smaller scale problems in urban areas" which is excluded from the definition of flooding by the FDM. Consequently, this clause would have limited relevance to FRM and no changes are recommended.
6.7 Environmentally Sensitive Land – riparian land and watercourses	*(1) The objective of this clause is to protect and maintain the following:* *(a) water quality within watercourses,* *(b) the stability of the bed and banks of watercourses,* *(c) aquatic and riparian habitats,* *(d) ecological processes within watercourses and riparian areas.* *(2) This clause applies to land identified as "Environmentally Sensitive Land" on the Riparian Lands and Watercourses Map.* *(3) In deciding whether to grant development consent for development on land to which this clause applies, the consent authority must consider:* *(a) whether or not the development is likely to have*	As with clause 6.4, this clause addresses certain water related matters, that are indirectly related to FRM. In this case the clause is focussed on managing environmental, and in particular biodiversity, impacts. No changes are recommended for FRM purposes.

LEP Clause	Sutherland LEP 2015	Comment
	any adverse impact on the following: *(i) the water quality and flows within the watercourse,* *(ii) aquatic and riparian species, habitats and ecosystems of the watercourse,* *(iii) the stability of the bed and banks of the watercourse,* *(iv) the free passage of fish and other aquatic organisms within or along the watercourse,* *(v) any future rehabilitation of the watercourse and riparian areas, and* *(b) whether or not the development is likely to increase water extraction from the watercourse, and* *(c) any appropriate measures proposed to avoid, minimise or mitigate the impacts of the development.* *(4) Development consent must not be granted for development on land to which this clause applies unless the consent authority is satisfied that:* *(a) the development is designed, sited and will be managed to avoid any significant adverse environmental impact, or* *(b) if that impact cannot be reasonably avoided—the development is designed, sited and will be managed to minimise that impact, or* *(c) if that impact cannot be minimised—the development will be managed to mitigate that impact.*	
6.9 Limited development on foreshore area	While this clause primarily has relevance to ocean related coastal hazards, clauses 6.9(3)(i) 6.9(4)(f) require a consideration of: *(i) it has considered sea level rise or change of flooding patterns as a result of climate change.* *(f) management of any rise in sea level or change of flooding patterns as a result of climate change.*	Future reviews of the DCP could consider including specific controls regarding climate change as discussed in this report. Note Council's Sea Level rise Policy was updated on in July 2020 as discussed in this report..

LEP Clause	Sutherland LEP 2015	Comment
6.10 Development on the foreshores of Port Hacking, Georges River, Woronora River and Port Botany	*(1) The objectives of this clause are as follows:* *(a) to provide for the protection of the foreshore environment of the Georges River, Woronora River, Port Botany and those areas of Port Hacking that are not part of the coastal zone for the benefit of both present and future generations,* *(b) to protect, enhance, maintain and restore the foreshore environment, its associated ecosystems, ecological processes and biological diversity and its water quality,* *(c) to protect and preserve the natural, cultural, recreational and economic attributes of the foreshores,* *(d) to provide opportunities for public pedestrian access to and along the foreshores,* *(e) to recognise and accommodate ecological processes and climate change,* *(f) to protect amenity and scenic quality,* *(g) to protect and preserve rock platforms, beach environments and beach amenity,* *(h) to protect and preserve native foreshore vegetation,* *(i) to protect and preserve the aquatic environment,* *(j) to ensure that the type, bulk, scale and size of development is appropriate for the location and protects and improves the natural scenic quality of the surrounding area,* *(k) to ensure that decisions in relation to development involve consideration of the broader and cumulative adverse impacts of the development on the catchment.* *(2) This clause applies to land identified as "Foreshore" on the Foreshores of*	This clause has no direct relevance to specifically the study area or generally FRM at present. However, it could be considered as one potential mechanism to restrict development in the high hazard part of the floodplain, that is, the foreshore building line could be established such that it identifies areas where development is restricted because of environmental, cultural and scenic reasons already captured by the clause plus areas of high flood risk. This would emphasise the hazardous nature of this area and provide a consolidated consistent foreshore setback line for development.

LEP Clause	Sutherland LEP 2015	Comment
	Port Hacking, Georges River, Woronora River and Botany Bay Map. *(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority has considered the following:* *(a) existing public access to and along the foreshore for pedestrians (including persons with a disability) with a view to:* *(i) maintaining existing public access and, where possible, improving that access, and* *(ii) identifying opportunities for new public access,* *(b) the suitability of the development, its relationship with the surrounding area and its impact on the natural scenic quality, taking into account:* *(i) the type of development concerned and any associated land uses or activities (including compatibility of any land-based and water-based activities), and* *(ii) the location, and* *(iii) the bulk, scale, size and overall built form design of any building or work involved,* *(c) the impact of the development on the amenity of the foreshore, including:* *(i) any significant overshadowing of the foreshore, and* *(ii) any loss of views from a public place to the foreshore,* *(d) how the visual amenity and scenic qualities of the foreshores can be protected,* *(e) how biodiversity and ecosystems, including the following, can be conserved:*	

LEP Clause	Sutherland LEP 2015	Comment
	(i) native vegetation and existing wildlife corridors, *(ii) rock platforms,* *(iii) water quality of waterbodies,* *(iv) native fauna and native flora, and their habitats,* *(f) the effect of ecological processes and ecological hazards and potential impacts, including sea level rise:* *(i) on the development, and* *(ii) arising from the development,* *(g) the cumulative impacts of the development and other development on the catchment.*	

APPENDIX C: REVIEW OF EXISTING FRM DCP PROVISIONS

Chapter/Clause	Provision	Comment
Chapter 38 - Stormwater and Groundwater Management		
1.2. Controls for dwelling houses, alterations and additions to existing houses and dual occupancies	Developments are not to cause an increase in stormwater run-off with a number of exceptions for which some limited increase in runoff is permitted including vacant sites, new dwellings, alternations and additional of a certain scale, or does not impact council assets or a sensitive natural environment.	These provisions are aimed at controlling increased runoff from new development that could contribute to downstream flooding. While the exceptions are sensible as it would not be practical for such development to provide mitigation such as on-site detention, the cumulative impacts of these exceptions should be considered and managed by catchment wide mitigation measures if necessary.
1.3. All other built development, subdivision and works	Other developments are not to cause an increase in stormwater run-off with exceptions where some increase in discharge is permissible.	
2. Methods of Off-Site Disposal	Overland flow paths shall not be obstructed by development. Similar provision applies to all forms of development.	Flow paths could be affected by fencing and this is discussed in Chapter 40.
3. On-site rainwater retention and re-use	These provisions provide for water capture and reuse which indirectly reduce off-site discharge of stormwater which might contribute to downstream flooding.	While unlikely to have a major effect on reducing flooding such provisions are desirable for a range of environmental reasons. This, and similar clauses, should be reviewed and rationalised in conjunction with Chapter 40.
4. Infiltration systems 4.2 4.7 Controls for development across areas with different soil infiltration potential	Provides criteria for the on-site absorption of stormwater.	While unlikely to have a major effect on reducing flooding such provisions are desirable for a range of environmental reasons.
5. On-site detention	Provides criteria for the on-site detention.	While unlikely to have a major effect on reducing flooding such provisions are desirable prevent increased flooding associated with development.
Chapter 40 – Environmental Risk		
Part C - Flood Risk Management	The preface provides background on flood risk management in the LGA and flood studies undertaken	Could be deleted or minimised as content does not provide any controls nor is it essential to understanding and applying subsequent controls. If retained consider minor updates to reflect progress with FRMS&Ps and flood

Chapter/Clause	Provision	Comment
		mapping and changes to EP&A Act references, specifically: • Reference to "Initial Assessment Potential Flood Risk" mapping will ultimately be superfluous. • The range of flood risk precincts to be updated to reflect recommended changes that are adopted as a consequence of this FRMS&P. • Update currently adopted FRMS&Ps. • Update reference to S149 Certificates (now S10.7 Certificates) and/or review relevance of note regarding additional S149 Certificate notes – and delete if not essential.
1. How to use this chapter	Outlines the process to follow to apply the provisions of this Part of the DCP.	Generally, these provisions would require review to reflect recommended changes that are adopted a consequence of this FRMS&P. Consider including a process flow chart and hyperlinks to other relevant documents such as the LEP, Codes SEPP and any Technical Specifications if prepared.
2. Dictionary of Terms	Terms used in the dictionary are either unique to the DCP, or derived from the FDM or LEP. Typically, definitions should be consistent between LEPs and DCPs but not necessarily with the FDM.	Consider amendments to DCP defined terms: • Include a definition of FPL and FPA for the purposes of the DCP and the LEP that equates to the level and extent of the PMF without freeboard. • The definition of FDM should be corrected to refer to the "Floodplain Development Manual" not "Floodplain Management Manual" • Refine the definition of "habitable floor area" to deal with vagaries such as how to consider other land uses, what is a working area in a residential situation, what are valuable possessions Recommended new definitions that adapt the BCA definition for FRM purposes are: *In regard to residential development habitable floors is building space intended for regular and continual human occupancy. Such space generally includes areas used for living, sleeping, dining and cooking, but does not generally include bathrooms, toilets, access areas, storage areas, closets, or utility rooms where located within a discrete part of the building that is separate from that part*

Chapter/Clause	Provision	Comment
		intended for regular and continual human occupancy. *In regard to non-residential development habitable floors is building space intended for regular and continual human occupancy or where the core operations of the use occurs. Such space generally includes areas used for office or business activities, manufacturing and the storage of goods and equipment essential to the use, but does not generally include bathrooms, toilets, access areas, storage areas, closets, or utility rooms where located within a discrete part of the building that is separate from that part intended for to facilitate the core operations of the use.* • Amend definition of suitably qualified engineer to align with the Codes SEPP definition of professional engineer (clause 1.5) "who specialises in hydraulic engineering" (clause 3A.38) Include an appropriate definition for safe refuge that for example specifies: • minimum floor area per expected occupant (eg minimum 1-2m^2 per person) and adequate facilities to sustain the likely occupants of the building for period of time that they are likely to isolated • the refuge is to be part of a building certified by a suitable qualified engineer as capable of withstanding the forces of floodwater, debris and buoyancy up to and including a PMF.
3. Land Use Categories		Collapse the Essential Community Facilities and Sensitive Uses and Facilities' categories and called it "Sensitive and Hazardous Development" and include uses as specified in the 2021 Guideline under this category. This will provide greater with the NSW framework and simplify the DCP controls. Otherwise, appears to adopt the terms from the SSLEP. Review and ensure that all definitions currently align.
4. Objectives		Refine the number of existing objectives and incorporate flood related development principles as appropriate.

Chapter/Clause	Provision	Comment
Performance Criteria		Introduce performance criteria to complement the prescriptive controls and incorporate flood related development principles as appropriate.
5. Controls		
5.1 Controls that apply to all Development on Flood Prone or Potentially Flood Prone Land		Reword and simplify Controls 1 and 2. Where appropriate simplify controls and refer to technical specification. Update reference to 'potentially flood prone' to 'mapped as initial assessment' or some alternative that is reflected in the DCP flood risk management mapping in Control 1. Define FPA in Control 2 as recommended in this report. Define floodway in Control 3. Review need to revise Control 3 requiring all floodways to be retained as a "natural waterway" as opposed to maintaining flow paths and avoiding impacts on others
5.2 Controls for Development on Land Mapped 'Initial Assessment Potential Flood Risk'		Edit to simplify. Delete or amend if these areas are now fully informed by a flood study. Flood Risk Management Mapping should be made easily accessible e.g. through a hyperlink. Define "exacerbate" in Control 4. Refer to "suitably qualified engineer" as recommended to be redefined above.
Assessment Matrix		The following comments are provided if the matrix approach is kept (recommended).
General		The shading and legend typology should be made consistent. Controls may require review to marry with recommended revised flood risk mapping approach. Edit floor level controls 2 and 3 to remove reference to "residential" and "commercial/industrial" uses so controls to land uses as defined by the land uses categories. Define "refuge area" to provide clarity to Review Structural Soundness control 2.

Chapter/Clause	Provision	Comment
		Review Flood Effects controls to specify when an engineers report would not be required unless advised by Council. Review Car Parking control 4 to clarify what is intended by "warning systems, signage and exits." Review Car Parking control 6 to clarify the protection required by setting a minimum level for the crest of the basement entry driveway is relevant for any opening to a basement car park. Change reference to "evacuation" to 'emergency management" in line with contemporary terminology.
5.3 Development on Land mapped as Low Flood Risk		Review floor level 2 for "sensitive uses and facilities". Need to confirm whether the evacuation controls on residential development conflict with the 2007 Flood Planning Guideline and if so whether the control was in existence prior to then. A conflict is assumed and the controls are amended to comply with the guideline subject to evidence to the contrary.
5.4 Development on Land mapped as Medium Flood Risk		Excavation control 1 for Commercial and Industrial is superfluous. Delete evacuation control 6 applying to recreation and non-urban uses, as this could be impractical for facilities such as parks. Other risk management controls would apply. Car Parking and Driveway Access controls Clarify conditions 1 and 3 below and review if can be applied. It is recommended that residential garages should be at the 1% + 200mm, carports at the 1% AEP (as nothing else on the ground) and do not condition driveway access on "normal" residential lots. Existing controls on driveways for individual dwellings could be considered excessive and inadvertently encourage driving through floodwaters. Controls on floating of cars on an individual residential lot is excessive. The tying down of vehicles would not be practical and cars in any case are likely to be in the carport or garage which will be at the 1% AEP and above while vehicles parked in unspecified locations cannot be reasonable managed.

Chapter/Clause	Provision	Comment
		Undertake a flood engineering and emergency management review of controls relating to basement car parking.
5.5 Development on Land mapped as High Flood Risk		Clarify the manner by which proposed development in the High FRP is treated as recommended by this report (see also **Appendix E**.

APPENDIX D: PELIMINARY REVISED PLANNING MATRIX

Planning Consideration	Flood Risk Precincts (FRPs)														
	High Flood Risk					**Medium Flood Risk**					**Low Flood Risk**				
	Sensitive & Hazardous Development	Residential	Commercial & Industrial	Recreation & Non-Urban	Concessional Development	Sensitive & Hazardous Development	Residential	Commercial & Industrial	Recreation & Non-Urban	Concessional Development	Sensitive & Hazardous Development	Residential	Commercial & Industrial	Recreation & Non-Urban	Concessional Development
Floor Level	3	2,4,6,7	2,4,6.7	1	5,6,7	3	2,4,6,7	2,4,6,7	1	5,6,7	3		2,4	1	5
Building Components	2	1	1	1	1	2	1	1	1	1	2		1	1	1
Structural Soundness	3	1or2	1or2	1	1	3	1or2	1or2	1	1	3		1or2	1	1
Flood Effects & Overland Flow Effects	2	2	2	2	2	2	2	2	2	2			1	1	1
Car Parking & Driveway Access	1,2,3,4,5, 6	1,2,4,5,6	1,2,4,5,6	4,5,6	4,5,6	1,2,3,4,5, 6	1,2,4,5,6	1,2,4,5,6	4,5,6	4,5,6	1,2,3,4,5,6		1,2,3,4,5, 6	4,5,6	4,5,6
Emergency Management	1,2,3,4,5, 6,7	1,2,4,5,6	1,2,4,5,6	3,4,5,7	1,2,4,5,7	1,2,3,4,5, 6,7	1,2,4,5,6	1,2,4,5,6	3,4,5,7	1,2,4,5,7	1,2,3,4,5,6		1,5,6	5,6,7	1,2,4,5,7
Management & Design	2,3		1,3	1,3	1,3	2,3		1,3	1,3	1,3	2,3		1,3	1,3	

.... = Subject to significant flood constraints (refer to General Note 1). .... = No controls.

General Notes:

1. Significantly Constrained Land: Where development types are likely to be incompatible with the hazards existing within the nominated part of the floodplain without substantial mitigation measures. Consequently the development may be found unacceptable unless the design of the development together with the mitigation measures can address any potential unacceptable amenity or environmental impacts. Alternatively, this may require a reduction in the otherwise anticipated development intensity for the land.
2. Filling: Filling of a site that is partially affected by flooding (if acceptable to Council) may change the flood risk precinct, and the associated development controls that apply to development on the site.
3. Multiple FRPs: Development controls relate to the FRP identified for the site. Where a site has two or more FRPs the relevant sets of controls apply to each risk precinct but for practical purposes the stricter controls would normally apply across the whole development..
4. Fencing: Refer to section XX of the DCP for planning considerations involving only the erection of a fence. Any fencing that forms part of a proposed development is subject to the relevant flood effect and structural soundness considerations of the relevant category.
5. Freeboard: Where required the following freeboard heights apply:
   a. Areas subject to riverine flooding: 500mm
   b. Areas subject to only overland flow flooding: XXXmm.
6. **Residential "Concessional Development"**: Except for group homes and seniors living, no controls apply to residential accommodation types of concessional development in the Low Flood Risk Precinct, including areas subject to riverine flooding.

Floor Levels

Performance Criteria

1. The cost of damages that may be incurred over the expected life of a development should be no greater than that which could be reasonably expected to be met by the occupants and/or the developer without Government assistance.

2. Despite the need to elevate floors, the development must remain acceptable with regard to its appearance and accessibility from the public domain and the amenity of the occupants.

Prescriptive Controls

1. All Floor Levels to be equal to or greater than the 5% AEP flood level

2. Habitable floor levels to be equal to or greater than the 1% AEP flood level plus freeboard.

3. Habitable floor levels shall be no lower than the PMF level.

4. Non-habitable floor levels shall be no lower than the 5% AEP level.

5. Floor levels shall be equal to or greater than the level of the 1% AEP flood level plus freeboard. Where this is not practical due to compatibility with the height of adjacent buildings, or compatibility with the floor level of existing buildings, or the need for access for persons with disabilities, a lower floor level may be considered. In these circumstances, the floor level shall be as high as practical and when undertaking alterations or additions, no lower than the existing floor level.

6. Where floor levels are to be raised to address flood risk considerations, open undercroft areas must be acceptably designed to be integrated into the architecture of the development and to avoid the accumulation of rubbish and the potential to harbour vermin.

7. Where a building is elevated to reduce flood hazard, subject to an assessment as to acceptability on amenity, the undercroft area is to remain open to permit the free flow of water under the building. A restriction shall be placed on the title of the land, pursuant to Section 88B of the Conveyancing Act, where the lowest floor is elevated more than 1.5m above finished ground level, confirming that the under croft area shall not be enclosed.

Building Components & Method

Performance Criteria

1. All structures to have flood compatible building materials below the prescribed floor flood planning level.

Prescriptive Controls

1. All structures to have flood compatible building materials below the 1% AEP flood level plus freeboard.

2. All structures to have flood compatible building components below the PMF level.

Structural Soundness

1. The building is designed to remain structurally sound in a flood equal to the prescribed minimum floor flood planning level.
2. The building is designed to remain structurally sound in a PMF, if it is to contain a refuge area.
3. The building is designed to remain structurally sound in a PMF.

Flood Effects

Performance Criteria

1. Development does not detrimentally increase the potential flood affectation on other development or properties either individually or in combination with the cumulative impact of development that is likely to occur in the same floodplain.
2. Development should not change the height or behaviour of flood waters elsewhere in the floodplain in a manner which is likely to materially and adversely impact other property. The assessment of these effects must include the potential for similar impacts that would arise as a consequence of other development in the floodplain that has the potential to occur in the future under current zoning and planning controls

Prescriptive Controls

1. Adequate information to be provided to demonstrate that the development should not increase the impact of flooding on other properties in the floodplain.
2. An engineer's report shall be provided to certify that the development will not increase flood effects elsewhere, having regard to:
    - loss of flood storage
    - changes in flood levels, flows and velocities caused by alterations to the flood conveyance; and
    - the cumulative impact of multiple potential developments in the floodplain.

Car Parking and Driveway Access

Performance Criteria

1. Measures will be in place to warn people not to drive out of car parking areas where this would be dangerous and provide guidance and facilities to be able to safely exit the carpark.
2. All reasonable and practical measures are implemented to reduce the likelihood of motor vehicles being damaged by a flood.
3. All reasonable and practical measures will be in place to manage the potential vehicles floating and causing damage or becoming debris during a flood

Prescriptive Controls

1. The minimum surface level of open car parking spaces or carports shall be no lower than the 1% AEP flood or the level of the crest of the road at the location where the site has access to the road.

2. Garages shall have a minimum finished floor level no lower than the 1% AEP flood plus 200mm freeboard.

3. Except for single dwelling houses, the level of the driveway providing access between the road and parking space must be no lower than 300mm below the 1% AEP flood or such that the depth of inundation during a 1% AEP flood is not greater than either the depth at the road or the depth at the car parking space.

4. Basement garages and car parking areas with a floor level below the 5% AEP flood or more than 0.8m below the 1% AEP flood level, shall have a pump-out system, adequate warning systems, signage and exits. Warning systems shall include both audible and visual alarms and there shall be continuously rising pedestrian route between all parts of a basement car park and an exit.

5. Restraints or vehicle barriers shall be provided to prevent floating vehicles leaving a site during a 1% AEP flood, other than for single dwelling houses. A flood depth of more than 200mm will cause serious water damage to a typical vehicle and a depth of 300mm is sufficient to cause a typical vehicle to float.

6. Basement car parking levels shall be protected from inundation by a 1% AEP flood (plus 200mm). Where required, the crest of the driveway providing access between the road and basement garages will need to be a minimum of 200mm above the level of the 1% AEP flood.

Emergency Management

Performance Criteria

1. The development should be designed and be able to be managed to ensure that during a flood emergency all occupants are capable of seeking safe refuge.

Prescriptive Controls

1. Reliable access for pedestrians or vehicles shall be provided from a minimum level equal to the lowest habitable floor level to an area of refuge above the PMF level. Where safe and practical this should involve evacuation to an area outside of the PMF extent.

2. Adequate exits shall be available to allow safe and orderly evacuation without increased reliance upon the SES or other authorised emergency services personnel.

3. Adequate flood warning systems, signage and exits shall be available to allow safe and orderly evacuation without increased reliance upon the SES or other authorised emergency services personnel.

4. The development shall be consistent with any relevant flood strategy, Floodplain Risk Management Plan adopted by Council or similar plan.

5. An engineer's report shall be provided to certify that an area of refuge is available if circumstances are possible where the evacuation of persons might not be achieved within an effective warning time

6. Applicant shall demonstrate that evacuation in accordance with the requirements of the DCP is available for potential development flowing from the subdivision proposal.

7. A site emergency response plan (FERP) shall be prepared.

Management and Design

Performance Criteria

1. The development should be designed and managed to ensure that during a flood it does not cause unacceptable levels of pollution and valuable goods are capable of being protected.

Prescriptive Controls

1. An area shall be available within the dwelling to store goods above the 1% AEP flood level plus freeboard.

2. Applicant shall demonstrate that an area is available to store goods above the PMF level.

3. No storage of materials which may cause pollution or be potentially hazardous during any flood is permitted below the 1% AEP plus freeboard.

Impact Figures for Blockage Analysis on Captain Cook Drive

Appendix E

FIGURE E1
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
CULVERTS ENTERING THE BAY BLOCKED 100% CHANNEL FILLED TO 1.0MAHD
50% AEP LOCAL EVENT, AR&R2019

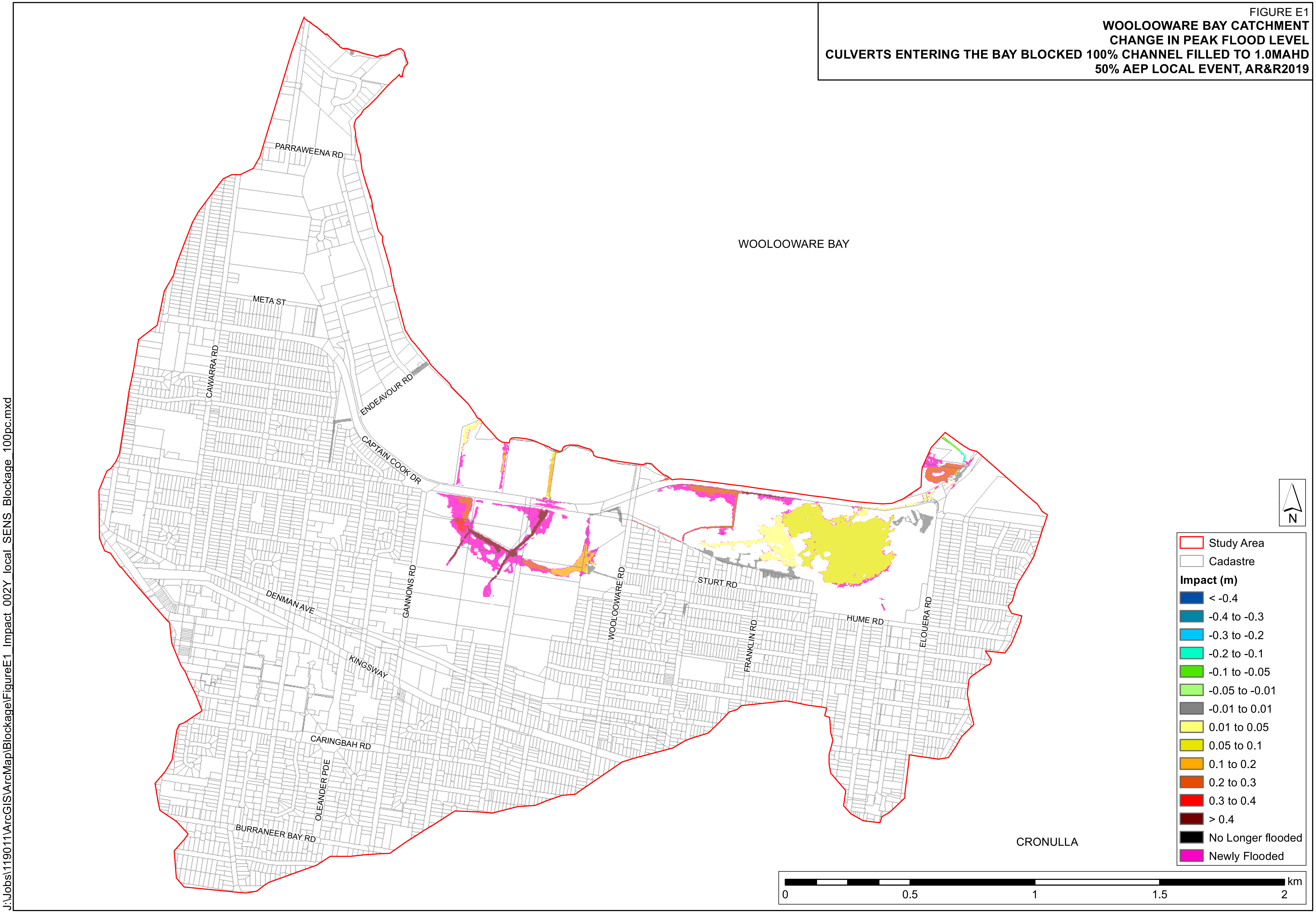

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FIGURE E2

WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
CULVERTS ENTERING THE BAY BLOCKED 100% CHANNEL FILLED TO 1.0MAHD
50% AEP EVENT, AR&R2019

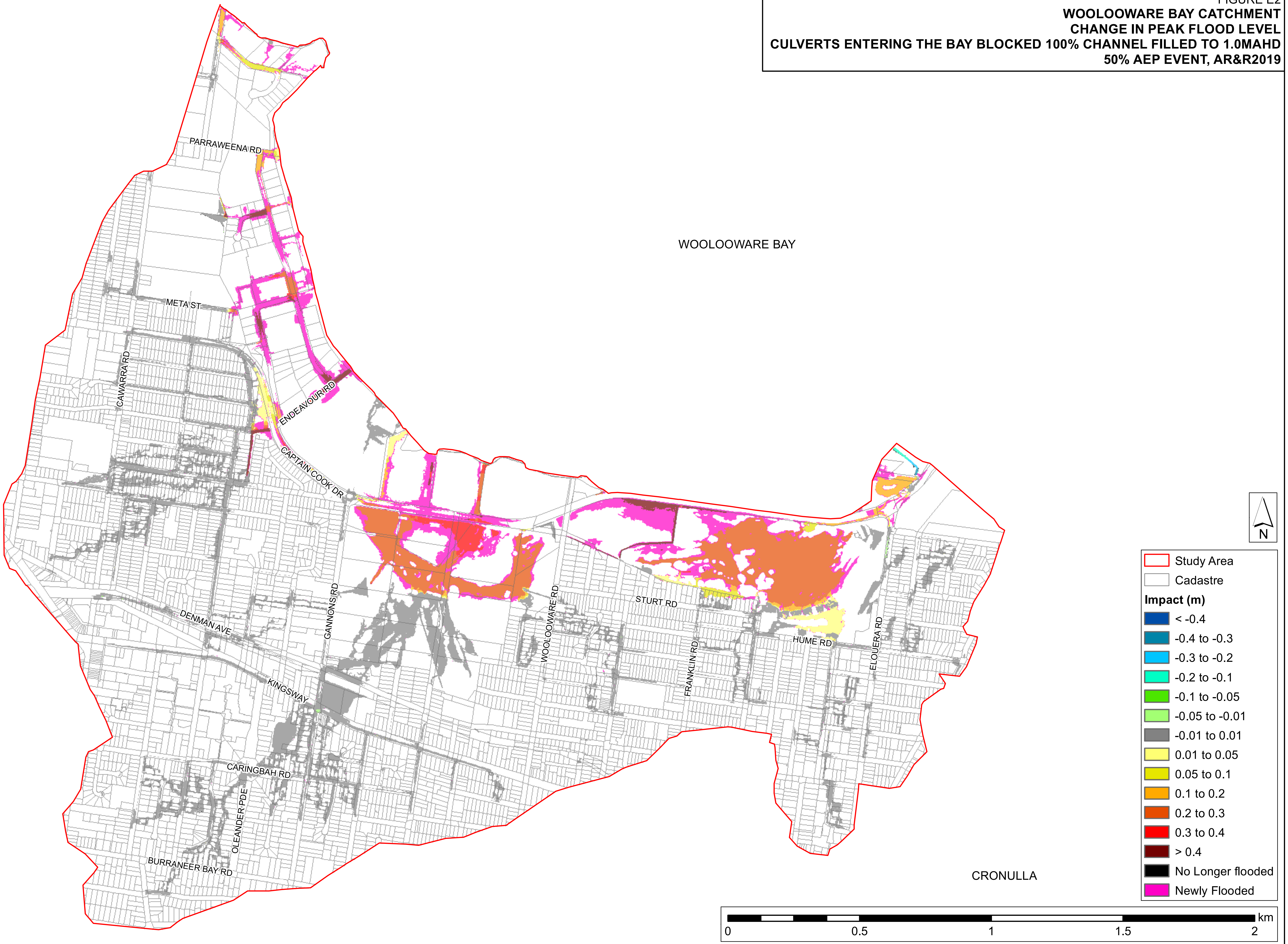

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FIGURE E3
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
CULVERTS ENTERING THE BAY BLOCKED 100% CHANNEL FILLED TO 1.0MAHD
20% AEP EVENT, AR&R2019

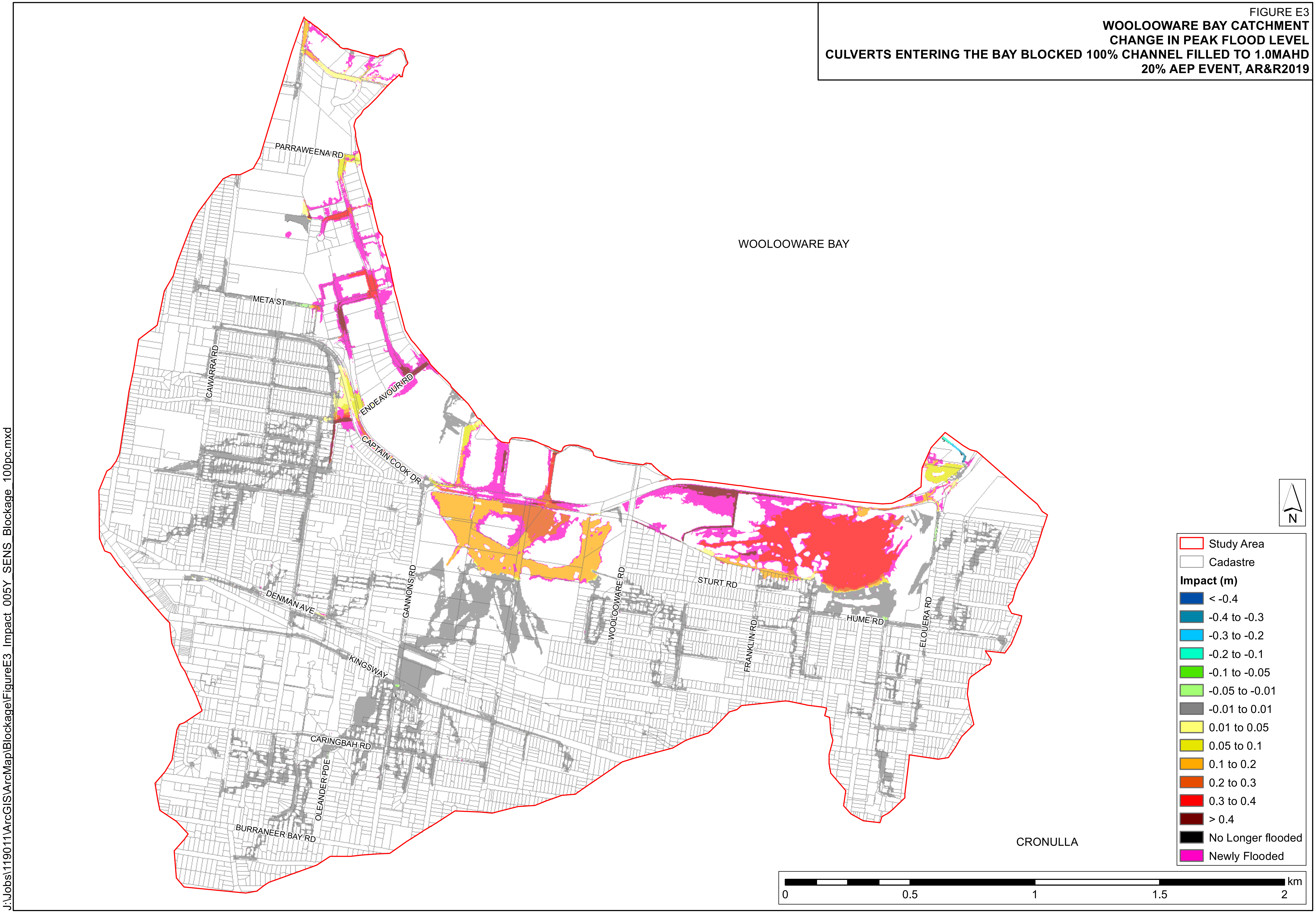

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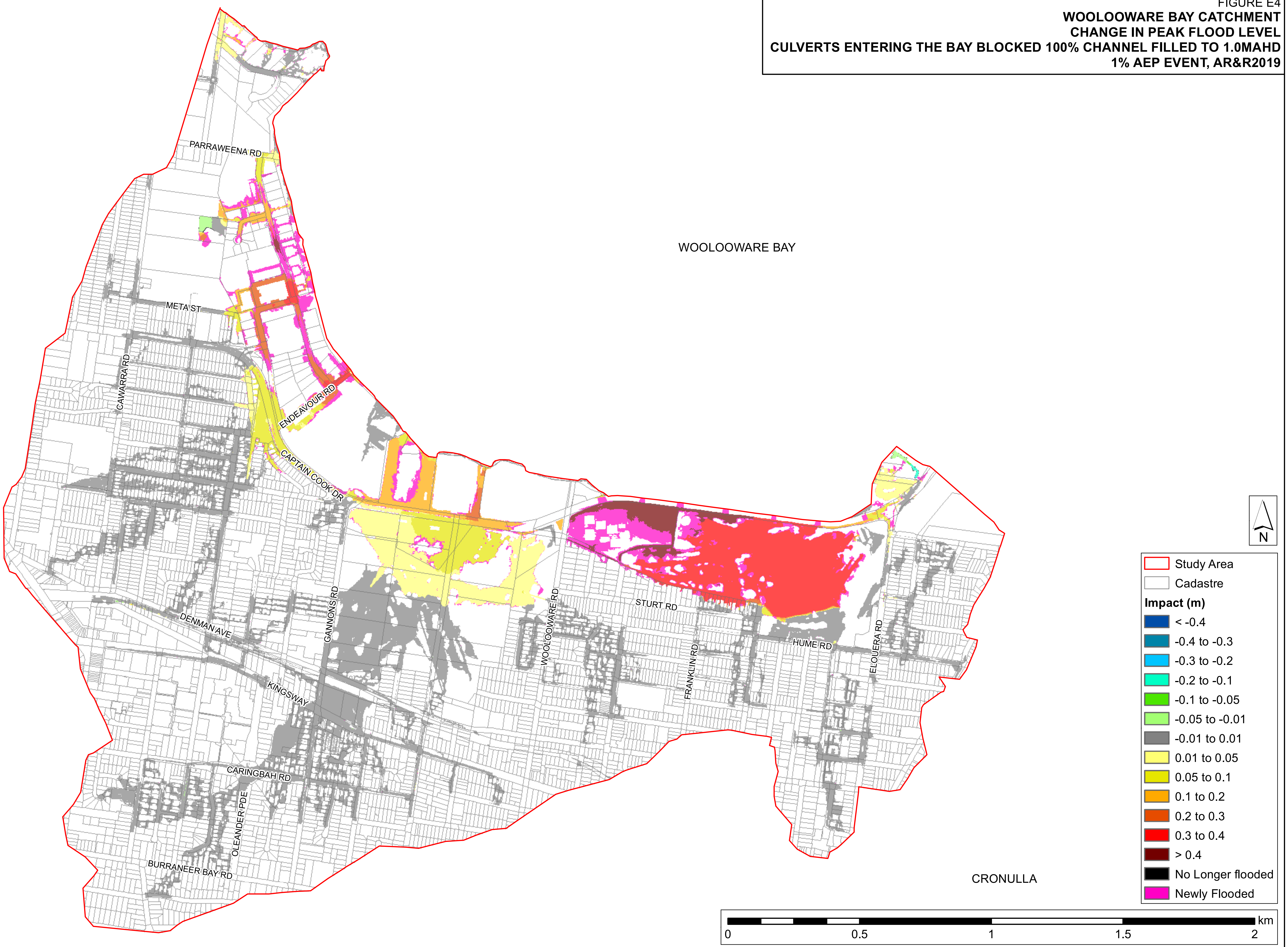
FIGURE E4
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
CULVERTS ENTERING THE BAY BLOCKED 100% CHANNEL FILLED TO 1.0MAHD
1% AEP EVENT, AR&R2019



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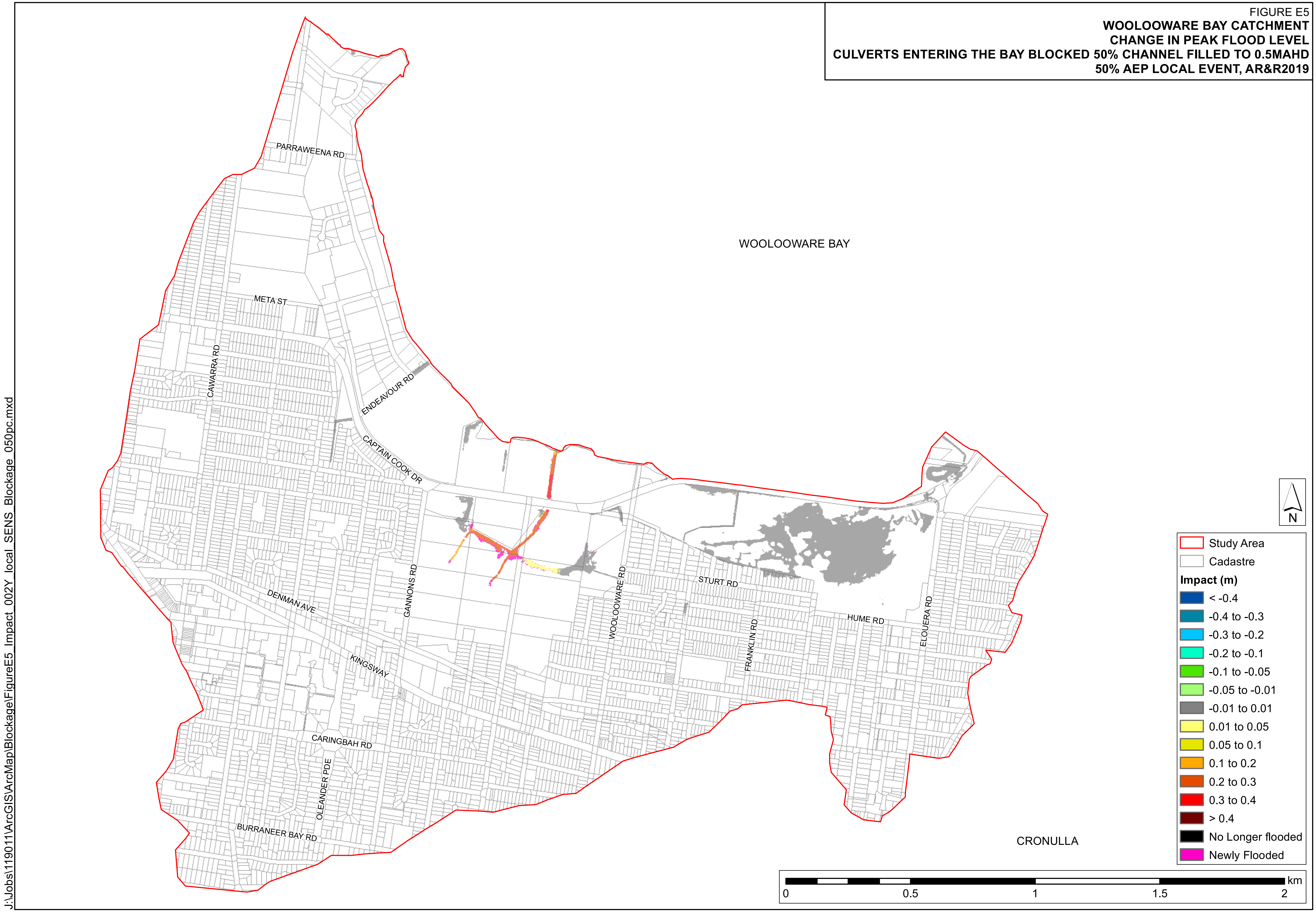
FIGURE E5
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
CULVERTS ENTERING THE BAY BLOCKED 50% CHANNEL FILLED TO 0.5MAHD
50% AEP LOCAL EVENT, AR&R2019
WOOLOOWARE BAY
PARRAWEENA RD
META ST
CAWARRA RD
ENDEAVOUR RD
CAPTAIN COOK DR
DENMAN AVE
GANNONS RD
KINGSWAY
WOOLOOWARE RD
STURT RD
HUME RD
FRANKLIN RD
ELOUERA RD
CARINGBAH RD
OLEANDER PDE
BURRANEER BAY RD
CRONULLA
N
Study Area
Cadastre
Impact (m)
< -0.4
-0.4 to -0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
0.3 to 0.4
> 0.4
No Longer flooded
Newly Flooded
0
0.5
1
1.5
2
km
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FIGURE E6
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
CULVERTS ENTERING THE BAY BLOCKED 50% CHANNEL FILLED TO 0.5MAHD
50% AEP EVENT, AR&R2019

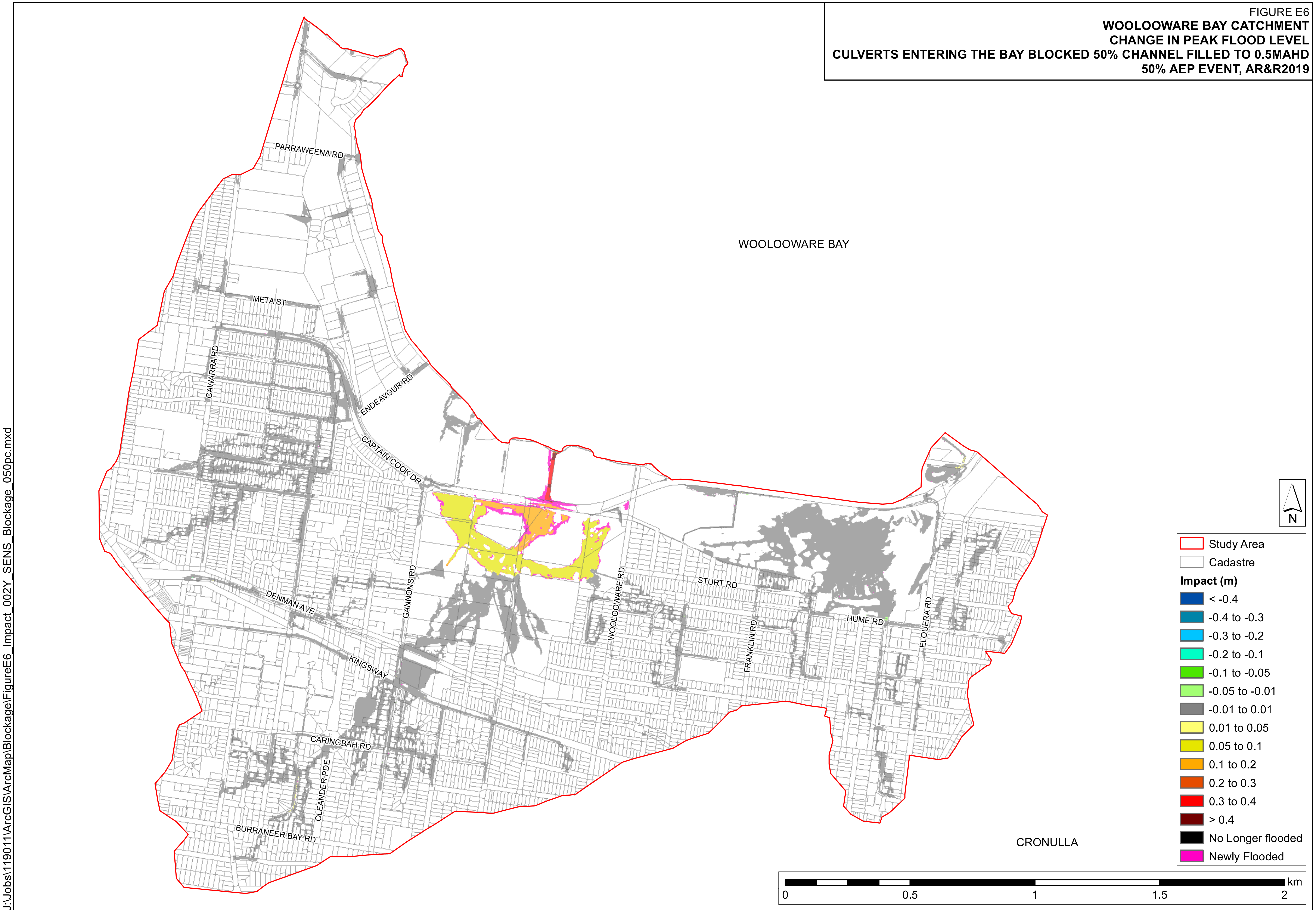

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FIGURE E7
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
CULVERTS ENTERING THE BAY BLOCKED 50% CHANNEL FILLED TO 0.5MAHD
20% AEP EVENT, AR&R2019

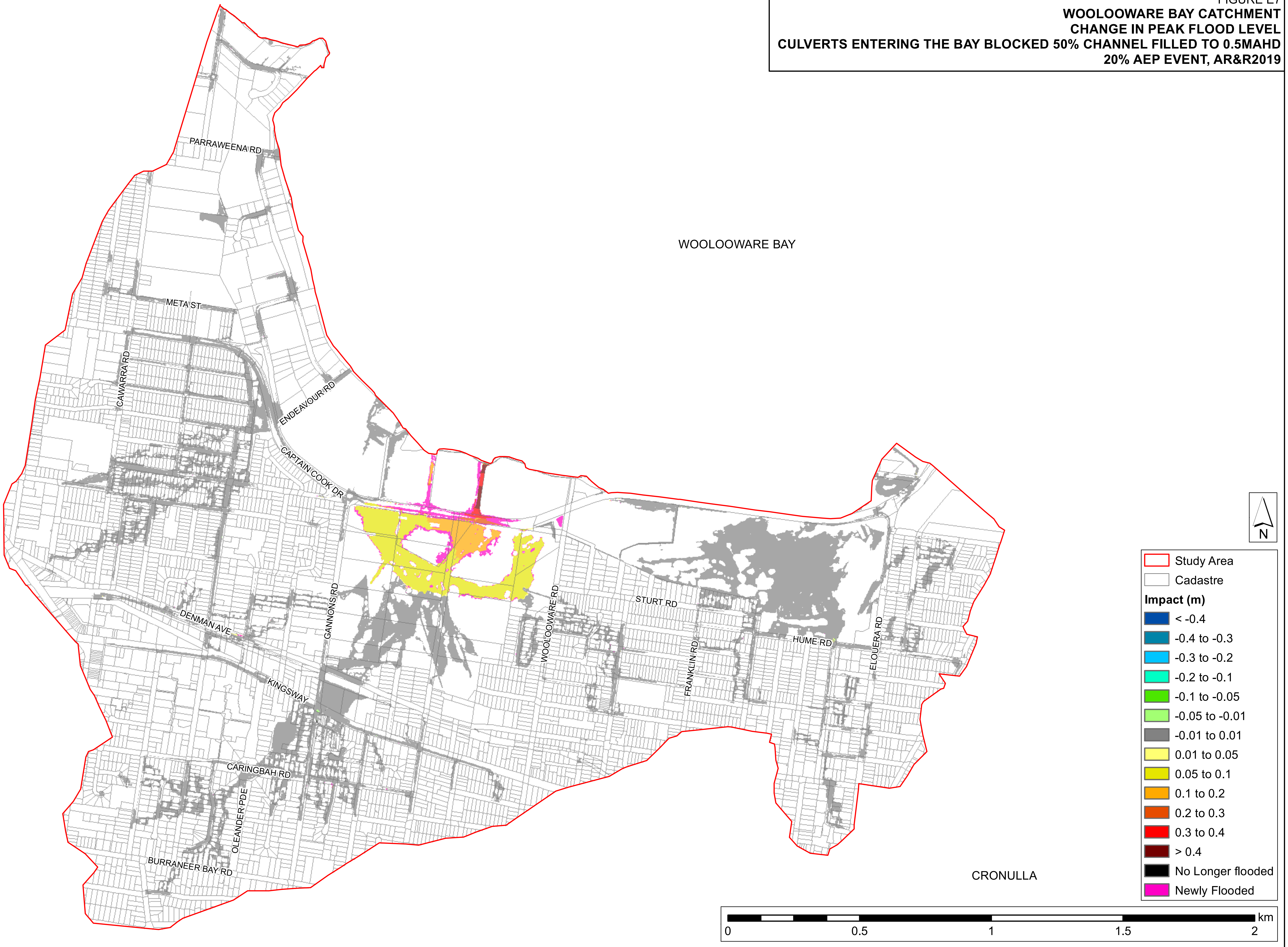

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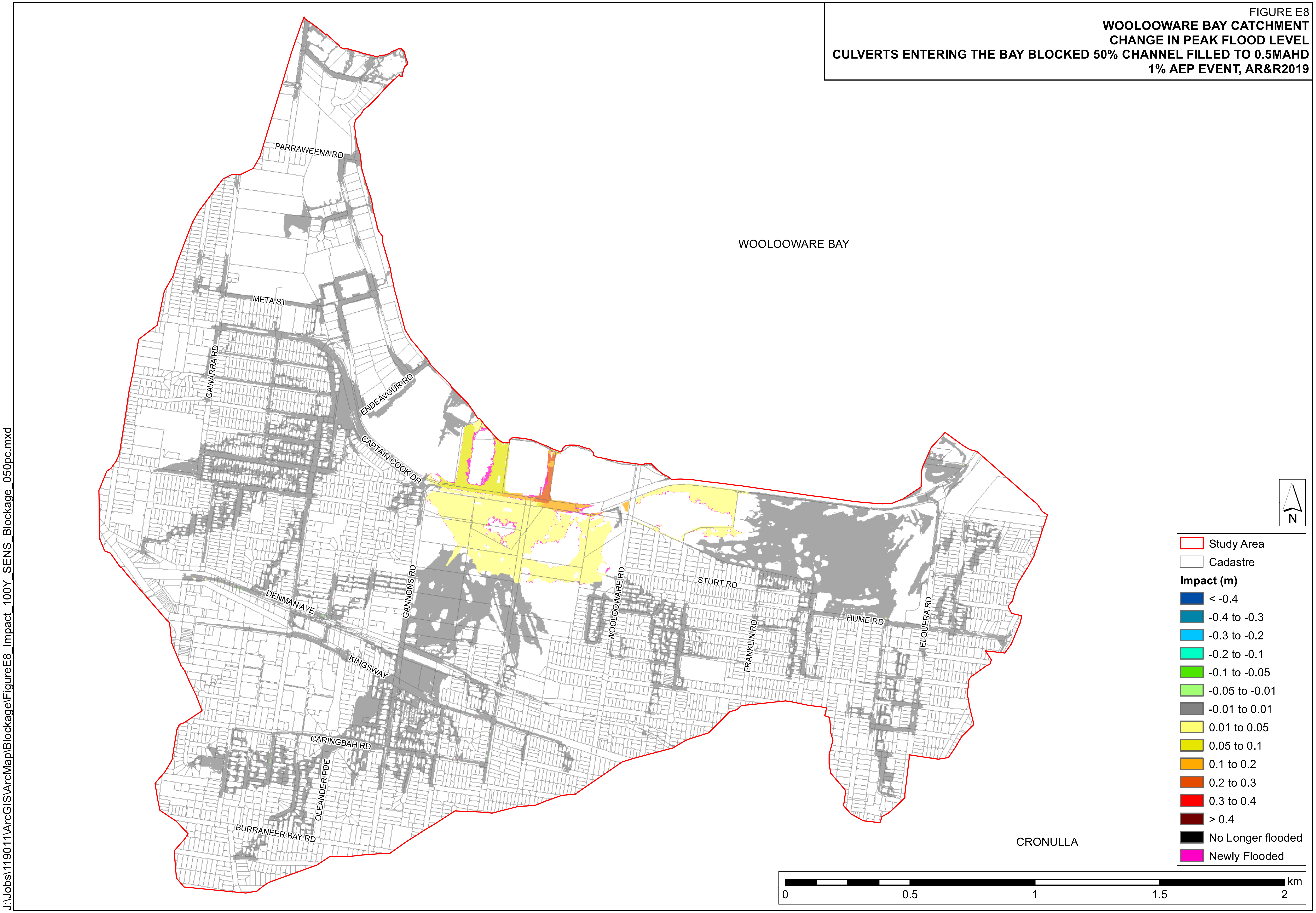
FIGURE E8
WOOLOOWARE BAY CATCHMENT
CHANGE IN PEAK FLOOD LEVEL
CULVERTS ENTERING THE BAY BLOCKED 50% CHANNEL FILLED TO 0.5MAHD
1% AEP EVENT, AR&R2019



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Detailed Review of 2014 Flood Study and ARR2019 Rainfalls

Appendix F

APPENDIX F: DETAILED REVIEW OF 2014 FLOOD STUDY AND ARR2019 RAINFALLS

F1. Review of March 2014 Woolooware Bay Flood Study (Reference 1)

The objective of this study was to define the existing flood behaviour in the catchment in terms of peak water levels, flows, velocities, and extents for a range of design flood extents up to the PMF. The scope included inundation from overtopping of the pit and pipe network as well as overland flooding (because of surcharging of Council's pit and pipe stormwater network).

In the absence of an extensive historical flood record, a flood frequency approach cannot be undertaken for the Woolooware Bay catchment. Therefore, design rainfalls were used in conjunction with the establishment of a hydrologic/hydraulic modelling system. A DRAINS hydrologic model was established which provided inflow hydrographs into the TUFLOW hydrodynamic model. The TUFLOW model incorporated both major subsurface drainage features and overland flow paths within the model extent. The two components were dynamically linked such that the model accounted for the interactions between the drainage system and overland flow behaviour.

F1.1. Broad Components of Work Undertaken

- Collection of available data (survey, rainfall, flood, pit and pipe data) and review of past flooding information.
- Undertaking a comprehensive community consultation and flood data collection process.
- Establishment and calibration of a rainfall runoff hydrologic model (DRAINS).
- Establishment and calibration of a 2D hydraulic model (TUFLOW.
- Determination of the design critical storm durations based on ARR 1987 rainfall data.
- Determination of design flood levels and extents.
- Sensitivity of the results to potential rainfall increases, sea level rise, blockage of the piped drainage system, hydraulic roughness, catchment imperviousness, elevated tidal levels in Botany Bay.
- Reporting and provision of relevant mapping for the design events.

F1.2. Key Points of the Report

- There was very limited suitable calibration data to verify the accuracy of the modelling system. There are a variety of reasons for this including.
    - o Lack of recorded peak levels for historical events.
    - o Significant changes to the catchment due to road infrastructure and other works which means some of the prior historical levels are not now applicable.
    - o The most recent calibration event modelled was of relatively small magnitude and thus does not reflect the extent of inundation in larger events.
    - o The available gauged rainfall data may not be reflective of the overall catchment rainfall.
- The results are based on ARR 1987 which has now been superseded by ARR 2019. The main change being updated design rainfall depth, losses and temporal pattern data meaning that the peak levels will change.

- There is no suitable stream gauge data in the catchment for model calibration.
- TUFLOW adopted a 3m grid and used ALS collected in October 2005 by AAMHATCH where the expected nominal point accuracies (based on a 68% confidence level) are ±0.15m (vertical accuracy).
- A key outcome from the report was to highlight the importance of collecting and maintaining a database of historical rainfall and flood height data. It is vital that information from future flood events is collected within 24 hours and the magnitude and direction of flow paths through private property recorded. This information would significantly improve the accuracy of the design flood levels and extents and ensure that known flood areas are identified and assessed.
- An analysis of historical daily and pluviometer rainfall data was undertaken.
- A community consultation programme was implemented with Council's assistance in early 2012. Approximately 4,600 questionnaires were issued to residences (with 404 responses) within the study area and an online survey form was also made available on Council's website. This was followed by phone calls and e-mail correspondence with selected respondents. The returned questionnaires and online survey results were compiled into a database. The key findings were:
    - the May 2003 event was a well-remembered event during which 15 residents experienced flooding in one form or another. The other known historic events (1975, 1986, 1990) also resonated with a small number of residents.
    - inundation of properties (not necessarily above floor level) and roads in the Woolooware Bay catchment were a major issue for approximately 103 and 96 respondents respectively.
    - only 5 of the 103 respondents who have experienced property flooding have had flood waters enter their home (water above floor level).
    - rainfall events which cause drainage issues (i.e., inundation of private property) occur relatively often (with 27 respondents being affected by flooding issues 3 or more times each year).
    - flooding in the Woolooware and Cronulla golf courses as well as several recreational parks/fields were noted by 97 of the respondents.
    - 57 respondents noted instances of drainage blockage resulting in localised flooding.
    - a small number of photographs of historic flood event were provided by the respondents though limited information could be gained regarding the observed flood behaviour. No specific flood levels or depths were provided but numerous flood locations throughout the catchment were indicated.
- Surcharging of the Council piped system will occur in less than an hour after the commencement of rainfall and will occur in events of 0.5 EY and greater (on average every 2 years).
- For this study, all design events up to the 0.5% event were based on a 1-hour peak storm burst embedded within a longer 12-hour duration storm. The 60-minute duration was adopted as critical for the PMF.
- Maps of design flood extents, depths, velocity, hazard, hydraulic categorisation, flood planning area and flood emergency response classification for communities were provided.

- Climate change sensitivity analysis was undertaken which indicated that for the 1% AEP flood event, a 10% increase in design rainfall intensity results in approximately 0.1 m maximum increase in peak flood levels, a 20% rainfall increase results in approximately 0.2m maximum increase in peak flood levels and a 30% rainfall increase results in approximately 0.3m maximum increase in peak flood levels (around the Jenola Park area). Sea level rise impacts are largely confined to the low-lying areas adjacent to Woolooware Bay.
- Hydraulic categorisation was defined as:
  - *Floodway = Velocity * Depth > 0.25 m²/s AND Velocity > 0.25m/s OR Velocity > 1m/s.*
  - *Flood Storage = Depth > 0.2m (provided that NOT categorised as Floodway).*
  - *Flood Fringe = Depth < 0.2m (provided that NOT categorised as Floodway or Storage).*
- Several flooding hot spots were identified in the catchment including:
  - Depression upstream of Hume Road in the Bando Road area.
  - Areas adjacent to the open channels at Edinburgh Close, Fenton Avenue and Yathong Close.
  - Overland flow paths such as Gannons Road, the Kingsway, Caringbah Road and Captain Cook Drive.
  - Woolooware and Cronulla golf courses, as well as majority of the playing fields; and
  - Generally, the low-lying areas adjacent to Woolooware Bay including Captain Cook Drive, Solander Fields, the football grounds, the industrial area at Resolution Drive, Endeavour Road, Northumberland Drive and Parraweena Road.
- The report was made available for the community from early October to November 2013. The community were invited to examine the report and make any comments or suggestions. More than 30 formal submissions from the community were received and a detailed response was made addressing all submissions.

In preparing the March 2014 Woolooware Bay Flood Study (Reference 1), several previous studies were made available for review by Council ranging from detailed drainage studies of individual lot development through to investigations of broader areas covering the lower Georges River floodplain. Key studies reviewed as part of the present assessment included:

- Initial Subjective Assessment of Major Flooding, 2004.
- Lower Georges River Floodplain Risk Management Study and Plan, 2011.
- Lower Georges River Stormwater Management Plan, 1999; and
- Sea Level Rise Risk Assessment for Sutherland Shire Council, 2011.

F1.3. Minor Studies Reviewed

- Stormwater drainage and water quality strategy for proposed re-zoning of the eastern side of the football ground, 2002.
- Hydraulic engineers report and detailed flood study, 2A Captain Cook Drive, Caringbah, 2004.
- Flood Study for proposed upgrading of Shark Park for Cronulla Sutherland Leagues Club

Ltd, 2007; and

- Flood study & drainage analysis report for 32-40 Cawarra Road, Caringbah, 2011.

Further descriptions of the above studies are provided in the March 2014 Woolooware Bay Flood Study (Reference 1).

F2. Australian Rainfall and Runoff 2019

F2.1 Overview

The ARR guidelines were updated in 2019 due to the availability of numerous technological developments, a significantly larger rainfall dataset since the previous edition in 1987 and development of updated methodologies. The rainfall dataset includes a larger number of rainfall gauges which continuously recorded rainfall (pluviometers) and a longer record of storms (events from 1985 to 2015 are included). As part of the current study sensitivity of the design event modelling using the ARR 2019 methodologies has been undertaken and a comparison made with the results provided in the 2014 Woolooware Bay Flood Study Report.

F2.2 ARR 2019 – Design Rainfall Update

Three major changes have been made to the approach adopted in ARR 1987 (Reference 3) for ARR 2019 (Reference 4 and Reference 5).

1. The recommended Intensity, Frequency and Duration (IFD) rainfall data and initial and continuing loss values across Australia have been updated based on analysis of available records (available on the Bureau of Meteorology (BoM) website).
2. ARR 2019 recommends the analysis of 10 temporal patterns for each storm duration to determine the critical storm event. The critical storm event for a duration corresponds to the temporal pattern which produces the maximum average peak value from the 10 storms and
3. The inclusion of Areal Reduction Factors (ARFs) based on Australian data for short (12 hours and less) and long durations (larger than 12 hours). ARFs are an estimate of how design rainfall intensity varies over a catchment, based on the assumption that large catchments will not have a uniform depth of rainfall across their entire area. Based on the size of the Woolooware Bay catchment an ARF was not used for this study.

F2.3 Accuracy of the 2019 IFD Data

The 2019 IFD data can vary significantly from the previous 1987 IFD data. This issue is addressed by the text below taken from the BoM's web site (May 2019).

> The 2019 IFDs are based on a greatly expanded rainfall database and use contemporary methods for analysis of the rainfall data. In addition, the length of record available for each station has been maximised through quality control processes and Region of Influence methods. The 2019 IFDs provide a better overall fit to the current rainfall database than the old IFDs.

As with all statistical methods, there is a level of uncertainty in the derived results due to the variability inherent in the data sample. In the 2019 IFDs this uncertainty has been reduced through the increased sample size afforded by the additional years of recorded data and inclusion of significant amounts of rainfall data from water agencies around the country.

The process of developing the new IFDs was guided and reviewed by a panel of experts set up by Engineers Australia. The differences in methods between the new IFDs and the ARR87 IFDs are summarised in the table below:

Method	New IFDs	ARR87 IFDs
Number of rainfall stations	Daily read - 8074 Continuous - 2280	Daily read - 7500 Continuous - 600
Period of record	All available records up to 2012	All available records to up ~ 1983
Length of record used in analyses	Daily read >= 30 years Continuous > 8 years	Daily read >= 30 years Continuous > 6 years
Source of data	Bureau of Meteorology & other organisations collecting rainfall data	Primarily Bureau of Meteorology
Extreme value series	Annual Maximum Series (AMS)	Annual Maximum Series (AMS)
Frequency analysis	Generalised Extreme Value (GEV) distribution fitted using L-moments	Log-Pearson Type III (LPIII) distribution fitted using method of moments
Extension of sub-daily rainfall statistics to daily read stations	Bayesian Generalised Least Squares Regression (BGLSR)	Principal Component Analysis
Gridding	Regionalised at-site distribution parameters gridded using ANUSPLIN	Maps hand-drawn to at-site distribution parameters, digitised and gridded using an early version of ANUSPLIN

F2.4 Comparison of At Site Frequency Analysis from a Specific Rain Gauge to the IFD Data on the BoM's Website

A frequent question asked is why doesn't the at site frequency analysis of a specific rain gauge within a catchment match up with the IFD data obtained from the BoM web site. This issue is addressed by the text below taken from the BoM's web site (May 2019).

> Although at-site frequency analysis of the Annual Maximum Series (AMS) of observed rainfall was an integral part of the method adopted for the 2019 IFDs, it was only one of many steps used to produce the new gridded, regional IFDs.
>
> A regionalisation method was applied to give more weight to longer record stations within each region. This improved the estimates of rare (less frequent) events. A spline interpolation method was then applied to the regionalised rainfall data from across Australia to estimate gridded values for the whole country. Factors including latitude, longitude, elevation and consistency with neighbouring sites were used, in addition to rainfall characteristics at recording sites, thus allowing more reliable interpolation of rainfall depths in data sparse areas.
>
> Rainfall values from a Generalised Extreme Value (GEV) distribution fitted to the AMS at a specific duration for a particular site will vary from the point values extracted from the grid of IFD values. Although each event in the AMS is a record of the actual rainfall at a site, these measured rainfall values are effectively point samples of the rainfall distribution

across Australia. Each point sample has its own uncertainty and does not represent completely the underlying population of rainfall values. The extracted grid values, created from the regionalised rainfall inputs, will generally fall within the 95% confidence limits of the GEV distribution for the specific duration at each location.

The length and period of record at a site makes a significant difference in the level of uncertainty of any at-site comparisons. Regionalisation was applied to the measured rainfall data to effectively smooth out the effects of sampling uncertainty.

F2.5 Loss Data

Initial and continuing loss values are available from the ARR 2019 data hub. There is no gauge with a flow rating curve in the catchment thus it is impossible to derive the loss values from historical events.

The loss values adopted in the 2014 Woolooware Bay Flood Study used a combination of ARR 1987 recommendations and previous studies as ARR 1987 was not prescriptive in determining loss rates.

Current guidelines recommend using a range of initial losses (Table F1) that depend on the duration and the storm AEP. The data hub suggests a continuing loss of 2.1mm/h but Reference 5 suggests applying a factor of 0.4 to this value thus a continuing loss of 0.84 mm/h was adopted.

Table F1: Loss Values from the Data Hub

	AEP (%)					
Duration Minutes	50	20	10	5	2	1
60	15.5	8.9	9	9.9	8.6	5.9
90	15.2	8.8	8.9	8.8	8.5	7.3
120	15	9	9.7	9.1	8.6	6.3
180	16.1	10.1	10.8	9.9	10	6.3
360	16.5	10.7	11.2	10.1	9.8	5
720	20.7	14.9	14.3	13.4	12	5.5

In an urban environment such as Woolooware Bay the effect of the initial loss is negligible due to the impervious nature of the catchment. Moreover, the small size of the Woolooware Bay catchment results in a short critical duration time and therefore the influence of the continuous loss on the flows is also small.

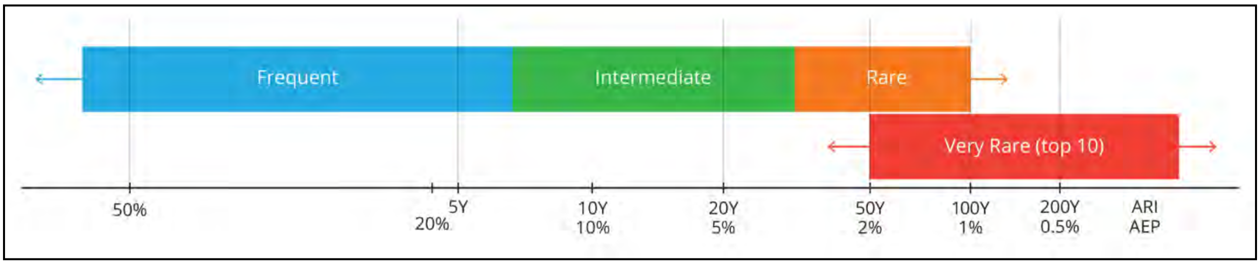
F2.6 Storm Temporal Patterns

ARR 1987 provided a single temporal pattern for each storm duration for:

- events less than a 30-year ARI; and
- for events greater than a 30-year ARI.

ARR 2019 provides several patterns for each storm duration. The temporal patterns were extracted from storms occurring across Australia and are different for each region. The data hub provides a table with all the temporal patterns that could be used at a given location. The temporal patterns are grouped in bins based on the intensity of the recorded storms as shown in Diagram F1.

Diagram F1: Temporal Pattern Bins



ARR 2019 recommends the use of 10 temporal patterns for design storm analysis. The 10 patterns have the same total rainfall depth, but there are differences in rainfall distribution across the storm duration. Some patterns may represent storms with intense bursts at the start, middle or end of the storm duration, others represent storms with multiple bursts, and some may represent storms with constant rainfall. Different patterns can produce different peak flood levels for the same catchment area depending on the catchment topography and response.

The representative temporal pattern (used as part of the critical duration analysis) is the pattern which produces peak flood levels just greater than the average of the 10 temporal patterns (not the temporal pattern which produces the largest peak level) for each storm duration. This can be determined by running each of the 10 temporal patterns through the hydrologic and hydraulic models and obtaining the average flood level or peak flow produced. The critical storm duration is the duration whose representative temporal pattern produces the maximum flow or level (i.e., the highest of the average values for all storm durations).

No single temporal pattern produced results just above the average of the 10 patterns across the entirety of a catchment and thus an envelope of the 30-, 120- and 540-minute events were adopted. Further details of this critical duration analysis are provided in Appendix C.

F2.7 Conclusions

The outcomes of the revision of the modelling undertaken as part of the present Flood Study are provided in Appendix B and C and should be adopted rather than those in the 2014 Flood Study.

Outcome of Community and Stakeholder Consultation

Appendix G

Woolooware Bay Floodplain Risk Management Study & Plan

Outcome of Community & Stakeholder Consultation

February 2022

Prepared By: Joga Jayanti

Stormwater & Waterways Assets Services

1. Introduction

In 2019 Council engaged specialist flood consultants WMAwater to prepare the Woolooware Bay Floodplain Risk Management Study & Plan (FRMS&P) in accordance with the floodplain risk management process outlined in the NSW Government's 2005 Floodplain Development Manual.

The key objectives of the Woolooware Bay FRMS&P were to:

1. review and update the 2014 Woolooware Bay Flood Study
2. identify, assess and recommend cost-effective floodplain risk management measures to reduce the risk of overland flooding in the catchment

A draft FRMS&P report was issued in October 2021. The draft FRMS&P was subsequently exhibited in November – December 2021 in order to obtain feedback on the draft plan and its recommendations. Public submissions were compiled and reviewed following exhibition.

This report discusses the consultation process and the key findings from the consultation.

2. Public Consultation Process

An online workshop was held on 23 September 2021 with several local consulting engineers who provided valuable feedback on their experience with the implementation of flood-related development controls as well as the proposed updates to DCP Chapter 40. No broad-scale community consultation was undertaken on the basis that there were no flood modification measures being proposed that Council would typically seek community feedback on.

Further, an online meeting was held on 30 September 2021 with NSW SES staff to discuss proposed emergency response measures.

In early October 2021, the draft FRMS&P was distributed to members of the Sutherland Shire Floodplain Risk Management Committee who oversee Council's administration of the floodplain risk management process. On 12 October 2021, the Committee met to discuss the draft Plan. In November 2021, Council subsequently endorsed the draft Plan for public exhibition.

The plan was publicly exhibited between 29 November and 24 December 2021. Council initially wrote to all residents and property owners with land identified as flood affected under the draft plan to notify them of the public consultation process. Information about the draft plan was also made available on Council's website on the join the conversation (JTC) page.

Material to assist in the public's review of the draft plan were also made available including:

- an information brochure
- answers to frequently asked questions
- draft FRMS&P

Residents were encouraged to comment on the draft Plan either by email, phone call back facility or through an online survey on Council's 'Join the Conversation' webpage.

During public exhibition period, an online meeting was held with Cronulla Golf Club staff to discuss stormwater and flood related matter.

3. Summary of Results

During the public exhibition period, Council received over 90 enquiries, which include direct phone calls, emails, enquiries on JTC, letters, etc. Out of 90 written comments, 23 were via the online survey, 64 via email and 4 via letters.

About 385 people visited the JTC page and 40 respondents answered the survey questionnaire. Of the 40 respondents to the online survey, 39 advised that they had read the information brochure or draft Plan report. Most respondents were concerned about flood affectation of their property and its impact on property value and/or insurance premium. In response to question about general approach to address flooding in the Woolooware Bay 50% of the respondents were either not sure or happy.

Regarding the level of community support and importance of proposed management measures, most of respondents agreed to voluntary fence modification and flood proofing. **Figure G1** below shows the level of support and prioritisation.

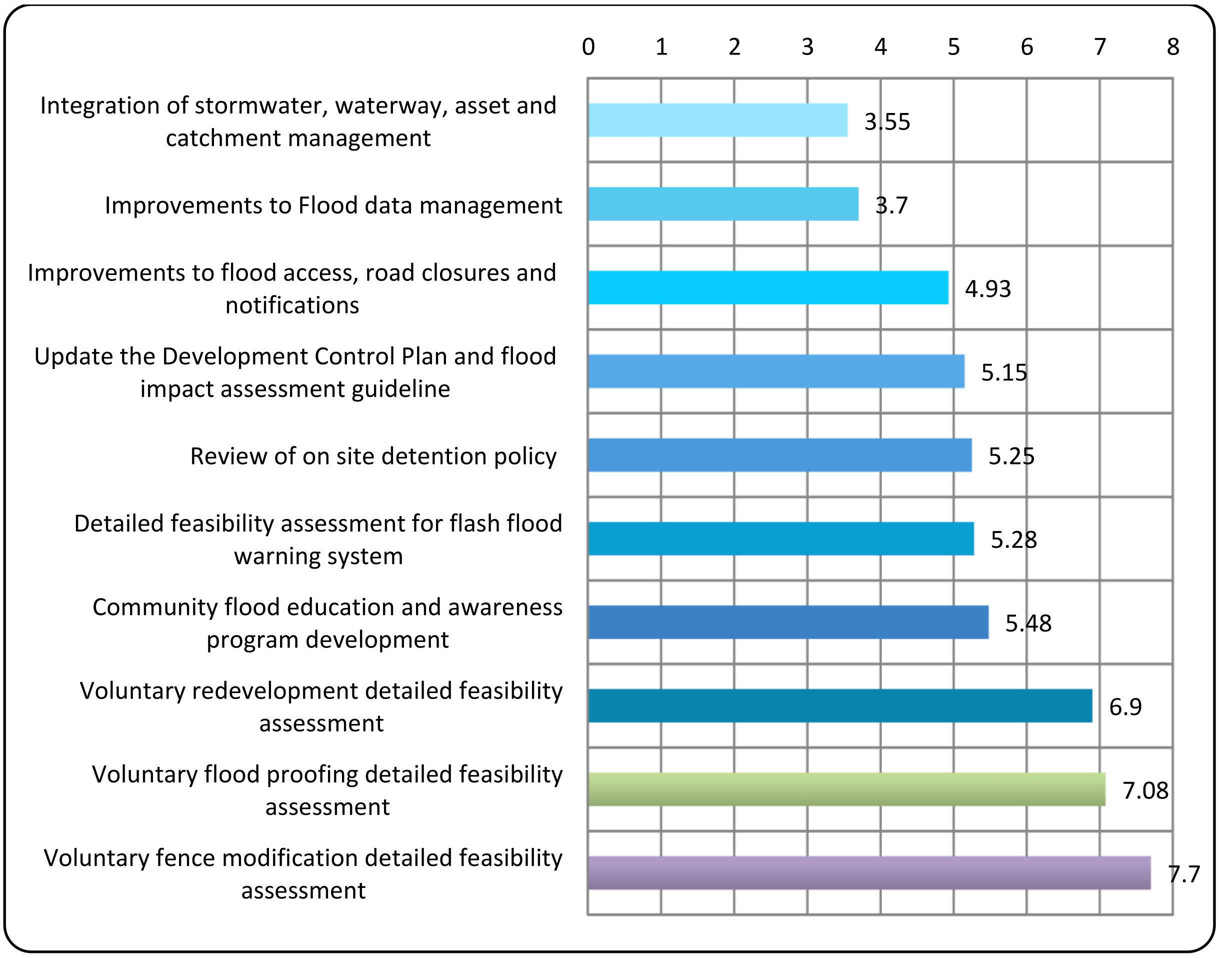


Figure G1 - Online Survey Response to proposed FRM measures

The key issues that emerged during the consultation process are given below.

1. **No flooding history:** Concerns were raised that many flood affected property owners have not experienced flooding in the past but their lot has been identified as flood affected in the Woolooware Bay FRMS&P.

2. **Impact on property value and insurance premium:** Concerns were raised mostly about the potential impact of flood notations attached to the Section 10.7 Planning Certificate on property value and likely increase in insurance premiums.

4. Discussion and Conclusion

The queries and concerns raised during the consultation period were addressed through telephone call backs as well as email responses and are now incorporated in the final Woolooware Bay FRMS&P.

The consultation process revealed some confusion between mainstream and overland flooding in the catchment. Flooding in general is perceived as mainstream flooding as most of the concerns were related to location of their property away from Woolooware Bay at higher elevation but still identified as flood affected. Council staff explained the main difference between mainstream and overland flooding and the community in general was satisfied with the explanation.

All properties up to the PMF are identified as flood affected and accordingly a flood notation has been attached to the Section 10.7 planning certificate. No minimum depth of inundation or minimum area of flood affectation were considered in tagging properties as flood affected. Hence, property owners from marginally affected lots were concerned that they never experienced flooding but their lot is identified as flood affected. The flood depth in most of the properties in the periphery of the catchment is shallow and impacts are minimal, and residents were further advised that the PMF event is an extremely rare event.

With regard to impact on property value and insurance premiums, residents were advised that there is no evidence to suggest that flood notation on the Section 10.7 certificate has a significant impact.